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## DUAL EDUCATION AS A MECHANISM FOR THE VOCATIONAL TRAINING OF FUTURE ENGINEERING SPECIALISTS IN VOCATIONAL EDUCATION INSTITUTIONS

**Mykola Zakharevych**, Candidate of Pedagogical Sciences, Associate Professor, Associate Professor Department of Vocational Education and Technology by Profiles, Uman National University.

ORCID: 0000-0003-3013-8644

E-mail: zakharuman@gmail.com

**Vadym Chychuk**, Candidate of Pedagogical Sciences, Associate Professor, Associate Professor Department of Vocational Education and Technology by Profiles, Uman National University.

ORCID: 0000-0002-8502-6458

E-mail: vadym.chychuk@udpu.edu.ua

*The article is devoted to the theoretical substantiation and practical analysis of the implementation of blended learning based on cloud technologies and virtualization into the system of dual training for engineering personnel in vocational education and training (VET) institutions of Ukraine. The study analyzes the current challenges of the domestic vocational education system under martial law, including infrastructure constraints, lack of physical equipment, and safety risks for underage students. The relevance of the study is reinforced by statistical data indicating a reduction in the number of VET institutions offering dual programs and a low level of Ukrainian business involvement in this process (only 1.4% of companies compared to 32.4% in the EU).*

*In the context of the sectoral reform, the provisions of the new Law of Ukraine "On Vocational Education" No. 4574-IX of August 21, 2025, are analyzed, which secures the academic and financial autonomy of institutions and legitimizes flexible learning models. The effectiveness of using cloud-based resource access models (SaaS, Azure Lab Services, AWS Academy) to deploy isolated virtual machines and simulators with specialized engineering software is substantiated, which eliminates the problem of incompatibility of students' home hardware. The didactic potential of virtual laboratories (VLabs) and digital twins (Digital Twins) technologies is analyzed as tools for safe "pre-dual" training of students, ensuring the formation of not only professional skills (Hard Skills) but also digital literacy, critical thinking, and soft skills (Soft Skills).*

*Special attention is paid to the transformation of the role paradigm of learning subjects (the teacher as a facilitator) and the integration of LMS Moodle with Google cloud services for end-to-end monitoring within the "educational institution – student – enterprise" triad. Technical and security risks of cloud migration are identified, and comprehensive cybersecurity levels (technical, organizational, and competence-based) are proposed. Based on the analysis of European experience (the MARLA and HubbS projects in Germany, apprenticeships in Poland, and the digitalization of Duálna Akadémia in Slovakia) and the best cases of Ukrainian companies (DTEK Grids, Interpipe, SoftServe), the prospects for creating a single national platform for sharing engineering simulators in the post-war reconstruction of Ukraine are outlined.*

**Keywords:** vocational education; dual education; training of future specialists in engineering specialties; digital transformation of education; vocational education institution; blended learning; information and educational environment; education seeker.

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## ДУАЛЬНА ОСВІТА ЯК МЕХАНІЗМ ПРОФЕСІЙНОЇ ПІДГОТОВКИ МАЙБУТНІХ ІНЖЕНЕРНИХ СПЕЦІАЛІСТІВ У ЗАКЛАДАХ ПРОФЕСІЙНОЇ ОСВІТИ

**Микола Захаревич**, кандидат педагогічних наук, доцент, доцент кафедри професійної освіти та технологій за профілями, Уманський національний університет.

ORCID: 0000-0003-3013-8644

E-mail: zakharuman@gmail.com

**Вадим Чичук**, кандидат педагогічних наук, доцент, доцент кафедри професійної освіти та технологій за профілями, Уманський національний університет.

ORCID: 0000-0002-8502-6458

E-mail: vadym.chychuk@udpu.edu.ua

*Статтю присвячено теоретичному обґрунтуванню та практичному аналізу впровадження змішаного навчання на засадах хмарних технологій та віртуалізації в систему дуальної підготовки інженерних кадрів у закладах професійної (професійно-технічної) освіти України. У дослідженні проаналізовано сучасні виклики вітчизняної системи професійної освіти в умовах воєнного стану, зокрема інфраструктурні обмеження, дефіцит фізичного обладнання та безпекові ризики для неповнолітніх здобувачів. Актуальність дослідження підсилюється статистичними даними, які свідчать про скорочення кількості закладів ПТО, що пропонують дуальні програми, та низький рівень залученості українського бізнесу до цього процесу (лише 1,4% компаній проти 32,4% у ЄС).*

*Особливу увагу приділено трансформації рольової парадигми суб'єктів навчання (викладача як фасилітатора) та інтеграції LMS Moodle з хмарними сервісами Google для наскрізного моніторингу в тріумвіраті «заклад освіти – учень – підприємство». Визначено технічні й безпекові ризики хмарної міграції та запропоновано комплексні рівні кіберзахисту (технічний, організаційний та компетентнісний).*

**Ключові слова:** професійна освіта; дуальна освіта; підготовка майбутніх фахівців інженерних спеціальностей; цифрова трансформація освіти; заклад професійної освіти; змішане навчання; інформаційно-освітнє середовище; здобувач освіти.

The contemporary system of vocational education and training (VET) finds itself at a bifurcation point, where traditional methodologies of engineering personnel training encounter the necessity of total digitalization and adaptation to conditions of constant uncertainty. Blended learning, based on the integration of face-to-face classes and digital platforms, has ceased to be merely an auxiliary tool and has transformed into a fundamental cornerstone for training skilled workers and engineers [14]. In the context of engineering education, this approach demands not just the use of computers, but the deep implementation of cloud computing and virtualization technologies, which allow mitigating the deficit of physical equipment and ensuring educational continuity even in high-risk zones [19].

The dual form of education, which inherently implies close synergy between an educational institution and the real economic sector, receives a new impetus thanks to cloud solutions. This allows synchronizing the theoretical framework that a student acquires remotely or in the classroom with practical skills practiced in production or within virtual simulation environments [20]. The transition to a model consisting of 30% theory and 70% practice, as declared in the Concept of Dual Training Specialist Development, requires a high level of technological maturity from VET institutions [8].

Current State of Research. In recent years, the theoretical and methodological foundations of blended learning and its integration into the educational process have become the subject of close attention among many domestic and foreign scholars. In scientific discourse, the concept of blended learning is viewed not simply as a mechanistic combination of face-to-face and remote classes, but as a flexible pedagogical philosophy of personalized, differentiated, and hybrid learning, which necessarily integrates the latest digital technologies to support and expand the daily cognitive activity of students [14]. Researchers emphasize that the effectiveness of such a model directly depends on constructing a coherent information-educational environment, wherein electronic components do not duplicate classical formats but qualitatively transform the interaction between the teacher and the student.

Digitalization becomes of particular importance in the field of vocational (vocational-technical) and engineering education. The implementation of blended learning in technical personnel training requires a transition from abstract textual platforms to the active use of cloud computing and virtualization technologies [15]. As noted by O. M. Spirin and O. S. Holovnia, the technological core of modern engineering didactics lies in the utilization of cloud virtual machines and isolated containers, which allows individualizing the selection of learning tools and resolving the critical issue of local IT infrastructure security [15].

At the same time, contemporary researchers propose viewing the virtualization of education not merely as a set of software tools, but as a profound psychological and pedagogical phenomenon. Thus, S. Lukashchuk interprets the virtualization of educational space as a natural component of a modern personality's life-creativity, which directly influences their comprehensive development and the formation of a «digital style of professional activity» [7]. H. M. Rozlutska, V. S. Nazarov, and V. Z. Ivaskevych conclude that the synergy of virtual platforms with cloud services and Google tools represents a strategic approach that adapts students to the requirements of a globalized digital professional environment, while stimulating their autonomy and independence [12].

Despite a significant number of works dedicated to separate aspects of utilizing cloud platforms and simulators, the question of their complex combination within the framework of the dual form of education in Ukraine remains under-researched. The majority of existing models are designed for classical distance learning in higher education institutions and do not account for the specifics of interaction between a VET institution and a partner enterprise, nor do they address the acute infrastructural and security challenges of martial law [5]. This necessitates the scientific substantiation and practical development of a blended learning model for engineers based on cloud technologies and virtualization, adapted to the modern realities of dual training in Ukraine.

The purpose of the article is to provide a theoretical substantiation and practical analysis of implementing blended learning based on cloud technologies and virtualization into the system of dual training for engineers in vocational (vocational-technical) education institutions of Ukraine.

The implementation of cloud technologies in the professional education of engineers ensures not only flexibility but also significant economic efficiency. The SaaS (Software as a Service) model allows educational institutions to abandon the maintenance of powerful server rooms and the purchase of expensive local licenses, shifting toward subscriptions to cloud solutions that update automatically [14].

The Azure Lab Services and AWS Academy platforms provide ready-made tools for creating virtual learning environments. For instance, Azure Lab Services allows an instructor to deploy virtual machines with pre-installed engineering software (SolidWorks, AutoCAD, Matlab) for an entire group within minutes [18]. This eliminates the problem of incompatibility between students' home hardware and the requirements of professional software.

AWS Academy offers specialized courses, such as «Data Center Technician», which combine deep theoretical training with laboratory work in the cloud. Although these courses possess an IT focus, they require basic knowledge of mechanics and electrical engineering, making them ideal for the interdisciplinary training of modern maintenance engineers [17].

Virtualization in the context of VET is not only about running operating systems in virtual machines but also about creating digital copies of physical processes and objects. Virtual laboratories (VLabs) are becoming a bridge between the theoretical course and working with real hardware.

Studies show that virtual laboratories serve as a powerful predictor of engineering education outcomes. The learning motivation effect when utilizing VLabs amounts to 3.571 (on the Hedges' *g* scale), which stands as one of the highest metrics among all educational technologies [22]. This is explained by the opportunity for safe experimentation and receiving instant feedback without the risk of damaging expensive equipment or suffering injuries [26].

The technology of digital twins represents the pinnacle of virtualization in Industry 4.0. It involves creating a virtual model of a physical asset that exchanges data with the original. The «Digital Twin on Smart Manufacturing» project (2024–2026), involving institutions from Italy, Spain, Germany, and other EU countries, is aimed at integrating these technologies into VET [21].

The educational curriculum of the project covers industrial systems virtualization, design, testing, and maintenance of machinery according to Industry 4.0 standards. This allows the realization of an ideal model of dual education: the enterprise provides a digital twin of its production line, and the student practices diagnostic and repair skills on this model within the educational institution before moving on to real manipulations on the shop floor [21].

The implementation of the dual form in Ukraine has faced serious challenges caused by war and demographic changes. An analysis of the KSE Institute report (June 2025) reveals a series of critical trends that demand an immediate response through digitalization tools [4].

The popularity of the dual form remains insufficient: in 2024, only 5,000 applicants chose this format during admission [27]. The number of VET institutions offering dual programs decreased from 223 in 2019 to 176 in 2024 (26.4% of the total number) [4].

One of the main inhibiting factors is the low level of business involvement as a whole – only 1.4% of Ukrainian companies participate in dual education, whereas the average figure in the EU stands at 32.4%. Meanwhile, the employment rate of dual program graduates is extraordinarily high at 81.4%, which exceeds the indicators of the traditional form by 13% [4]. This indicates the high quality of training, but insufficient scalability of the model.

The specificity of VET in Ukraine lies in the fact that 58.8% of students are minors, and 70.6% are 9th-grade graduates who are simultaneously obtaining complete secondary education. Labor legislation significantly limits working hours for individuals aged 14–15 (up to 12 hours per week during the school year), making them less attractive to business.

Furthermore, work in many engineering and manual trades (welding, heavy machinery) is prohibited for individuals under 18 due to hazardous working conditions [4].

This is precisely where virtualization and cloud technologies emerge as a critical solution. A student can undergo «pre-dual» training in a virtual workshop, practicing all hazardous operations in a VR headset, and enter a real workplace already at the age of 18, possessing full psychological and cognitive readiness for work [13].

The legislation in the field of dual and vocational education has undergone a substantial update. The Law of Ukraine «On Vocational Education» No. 4574-IX of August 21, 2025, defines new principles of academic autonomy for institutions [10].

The new legislation secures the right to self-governance for VET institutions, including financial and personnel independence. Institution heads are obliged to create conditions for the realization of individual educational trajectories, which effectively legitimizes the use of cloud platforms for flexible learning models [10].

An important aspect is the differentiation of training types:

1. Vocational training: initial acquisition of a qualification.
2. Retraining: changing profiles on the basis of already existing education.
3. Advanced training: improving skills within the profession [10].

A separate role is played by the Regulation on the Dual Form of Vocational Education (MES Order No. 1551), which regulates relations between the institution, the student, and the employer [3]. However, analysts point out the persistence of a certain confusion in specific clauses of this Regulation, which holds back the mass implementation of duality. There is also the problem of «gray» dual education, where enterprises do not officially register students to avoid paying 50% of the wage in favor of the educational institution [3].

When evaluating the essence of digitalization, it is important to consider virtualization as a large-scale socio-cultural and psychological phenomenon of the modern educational space. The virtual learning environment possesses specific characterological properties that influence the processes of comprehensive development and life-creativity of the future specialist's personality. Simultaneously, such virtualization acts as a strategic approach that adapts the educational paradigm to the requirements of the globalized labor market; however, it must function precisely as an effective supplement to the traditional model (which is a basic principle of duality), rather than its complete replacement [7].

The experience of European Union countries, particularly Germany, Poland, and Slovakia, provides valuable benchmarks for the Ukrainian reform.

Germany, as a leader in dual education, implements a large-scale strategy for the digitalization of vocational schools through the «Digital Pact for Schools». Projects supported by the Federal Ministry of Education and Research (BMBF) develop exemplary solutions for using Web 2.0 and mobile technologies in educational practice.

One of the most vivid examples is the MARLA (Masters of Malfunction) project, within which a VR application was created for training wind turbine maintenance specialists. Students practice fault diagnostics on a virtual offshore installation, allowing them to avoid massive transportation costs and life risks during training [20].

Moreover, Germany has implemented the HubbS (Hub for Vocational Schools) platform – a digital environment for sharing educational materials and facilitating communication among teachers across all 16 federal states. This prevents resource duplication and promotes the rapid dissemination of innovative methodologies [25].

The Polish VET system is based on close cooperation with sectoral organizations that constantly update the classification of professions in accordance with market needs. The «apprenticeship internship» (staż uczniowski) program allows for flexible integration of workplace assignment into the curriculum, using digital platforms to monitor student progress [25].

In turn, Chinese scientists M. Wu and P. Liu focus on a comparative analysis of the German model of «duale ausbildung» and the possibilities of its implementation in the Asian educational space, emphasizing the high adaptability of such systems to the needs of high-tech industries [20].

In Slovakia, the case of Duálna Akadémia is indicative, having undergone a journey of complete digital transformation of management with the assistance of the company Revolware. Replacing ad-hoc solutions with a structured Microsoft 365 architecture allowed the institution not only to stabilize its finances (saving over 1,700 euros per month in operating costs) but also to upgrade the quality of education through the implementation of electronic schedules and digital signatures for certificates [24].

Despite difficult conditions, Ukrainian companies demonstrate high efficiency in implementing elements of dual education using digital tools.

The DTEK Grids dual education project has been recognized as one of the best examples of economic accessibility on the state portal «Diia.Business». Students of energy specializations combine college studies with work on the company's modern equipment. Digital tools are utilized for remote theoretical learning during air raids and emergencies, ensuring the continuity of personnel training for critical infrastructure [11].

The experience of SoftServe illustrates an explosive growth in demand for cloud competencies. From 2021 to 2025, the share of DevOps/Cloud graduates grew fivefold. The Academy utilizes a blended learning model, where 80% of entry-level vacancies in the company are filled by graduates of its own educational programs, trained according to the dual principle in close cooperation with universities and colleges [23].

The large-scale migration of the educational process to the cloud gives rise to new threat vectors. For VET institutions, the main risks include phishing, attacks on servers containing exam results, and data leaks of minor students [16].

Therefore, we must turn our attention to cybersecurity strategies. Data protection in vocational education requires a comprehensive approach:

1. Technical level: mandatory use of VPN for accessing virtual laboratories, multi-factor authentication (MFA), and regular data backup in geographically remote cloud storage repositories [14].

2. Organizational level: development of clear instructions for safe network operations and the formation of «digital hygiene» among students and staff [21].

3. Competence level: inclusion of cybersecurity modules into all engineering specializations, since a modern engineer works within the networked Industrial IoT environment [21].

An important didactic aspect of the cloud transformation of dual education is the change in the role paradigm of educational process subjects. The implementation of virtual platforms requires instructors and industrial training masters to shift from the traditional reproductive model of knowledge transmission toward the functions of a facilitator, tutor, and moderator of the student's individual educational trajectory. The cloud-oriented environment

ensures continuous monitoring of educational achievements in real-time, which significantly increases the level of pedagogical management and optimizes feedback between the VET institution and the partner enterprise [1].

An important step in ensuring the accessibility and quality of education is the integration of specialized learning platforms (such as LMS Moodle) with public cloud services (in particular, the Google ecosystem), which creates favorable conditions for collaborative learning, group interaction, and a significant increase in the academic autonomy of students within the dual process [12].

Of particular significance is the development of the capacity for independent learning (Lifelong Learning). In the blended model, the student acts as a subject rather than an object of learning, independently planning their schedule and choosing trajectories on cloud platforms [14].

The post-war reconstruction of Ukraine will require a qualitatively new level of engineering training, where dual education based on cloud technologies will become a driver for industrial recovery.

Alongside technological advantages, the practical deployment of virtualization tools reveals a series of specific problems: the probability of hardware and software failures, fluctuations in the functioning speed of virtualized systems on outdated equipment, a lack of adapted methodical instructions for students, and uneven conditions for their independent work. To mitigate these factors, it is advisable to apply a variable approach (combining several technological solutions), as well as to optimize the IT infrastructure architecture on the basis of modern low-energy servers and contemporary Data Centers, allowing the consolidation of applications of different generations on a single platform [15].

A separate critical challenge when deploying the blended form of learning based on SaaS models is ensuring cybersecurity and protecting the personal data of students as well as the internal information of client enterprises. The integration of local LMS platforms with public cloud repositories accentuates the need to develop clear data encryption protocols, differentiate access rights (especially when working with virtual copies of real production systems), and comply with the requirements of the current legislation of Ukraine in the field of information protection [9].

**Conclusions and Research Prospects.** The article provides a theoretical substantiation and reveals the practical aspects of modernizing the dual form of engineering personnel training in VET institutions based on the systemic integration of blended learning, cloud computing, and virtualization technologies. The synthesis of scientific discourse and advanced pedagogical experience allowed reaching the following key conclusions:

1. It has been proven that under the conditions of contemporary socio-cultural transformations brought about by the deployment of the Industry 4.0 concept and the security challenges of martial law in Ukraine, the virtualization of the educational environment acts as a strategic didactic tool. It ensures flexibility, continuity, and inclusiveness of the educational process, effectively mitigating infrastructural limitations and the deficit of expensive physical equipment through the deployment of cloud-based resource access models.

2. It is substantiated that the use of cloud-oriented simulators (including SaaS, Azure Lab Services, and AWS Academy models), interactive training devices, and digital twin technologies (Digital Twins) allows for the successful realization of the competency-based approach. This toolkit ensures the formation of not only basic professional skills (Hard Skills)

and digital literacy in a safe, controlled environment, but also stimulates the development of flexible skills (Soft Skills), critical thinking, and the capacity for lifelong learning through an increase in students' academic autonomy.

3. It is established that the cloud transformation of the dual space fundamentally alters the role paradigm of learning subjects, turning the instructor and the industrial training master into facilitators and moderators of the student's individual educational trajectory. The integration of platforms like LMS Moodle with public Google services creates optimal conditions for collaborative interaction and ensures end-to-end monitoring of learning outcomes within the triad of «educational institution – student – client enterprise.»

4. It is determined that the large-scale implementation of virtualization tools is associated with a series of specific risks: technical failures, limitations of an outdated local hardware base, and cybersecurity threats. An effective way to overcome these challenges is the application of a variable technological approach, optimization of the IT infrastructure architecture based on modern low-energy servers and Data Centers, as well as the implementation of reliable encryption protocols and differentiation of access rights to protect the confidential information of partner enterprises.

Prospects for further research in this direction lie in the development of comprehensive scientific and methodical support and clear criteria for evaluating the effectiveness of the «pre-dual» virtual training of students. An urgent task also remains the design of a single national cloud-oriented platform (following European analogues) for sharing licensed engineering software and interactive simulators between vocational education institutions and stakeholders of the real economic sector.

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