INTEGRATED MODEL OF DIGITAL TRANSFORMATION OF HIGHER MILITARY EDUCATION: INNOVATIVE METHODS AND AI TECHNOLOGIES FOR TRAINING A NEW TYPE OF OFFICER

MODELO INTEGRADO DE TRANSFORMAÇÃO DIGITAL DO ENSINO SUPERIOR MILITAR: MÉTODOS INOVADORES E TECNOLOGIAS DE IA PARA A FORMAÇÃO DE UM NOVO TIPO DE OFICIAL

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ABSTRACT: This study aims to improve the educational model of specialized professional military education/training for future officers of the Armed Forces of Ukraine in higher military educational institutions through digital technologies. The research formalizes officer training by integrating technological, pedagogical, and managerial solutions, while distinguishing this specific training context from general or civilian educational systems. Methodologically, the study is based on systems analysis of the educational process and on the construction of integral indices and functional dependencies for assessing learning effectiveness. The results indicate that digital platforms, simulation environments, analytical tools, and algorithmic systems transform the organization of curricula, learning management, competency development, and assessment practices. The proposed model supports more precise evaluation of cadets' activities and the formation of individual learning trajectories. It also articulates professional, leadership, and digital competencies, clarifying the educational relevance of digital transformation within higher military training.

KEYWORDS: Digital Transformation. Military Education. Officer Training. Simulation Technologies. Digital Competencies.

RESUMO*: Este estudo tem como objetivo aprimorar o modelo educacional de formação profissional militar especializada para futuros oficiais das Forças Armadas da Ucrânia em instituições de ensino superior militar por meio de tecnologias digitais. A pesquisa formaliza a formação de oficiais ao integrar soluções tecnológicas, pedagógicas e gerenciais, ao mesmo tempo em que distingue esse contexto específico de formação dos sistemas educacionais gerais ou civis. Metodologicamente, o estudo baseia-se na análise sistêmica do processo educacional e na construção de índices integrais e dependências funcionais para avaliar a eficácia da aprendizagem. Os resultados indicam que plataformas digitais, ambientes de simulação, ferramentas analíticas e sistemas algorítmicos transformam a organização dos currículos, a gestão da aprendizagem, o desenvolvimento de competências e as práticas de avaliação. O modelo proposto permite uma avaliação mais precisa das atividades dos cadetes e a formação de trajetórias individuais de aprendizagem. Ele também articula competências profissionais, de liderança e digitais, esclarecendo a relevância educacional da transformação digital no âmbito da formação militar superior.*

PALAVRAS-CHAVE*: Transformação digital. Educação militar. Formação de oficiais. Tecnologias de simulação. Competências digitais.*

RESUMEN*: El objetivo de este estudio es mejorar el modelo educativo de la formación militar profesional especializada para futuros oficiales de las Fuerzas Armadas de Ucrania en instituciones de educación superior militar mediante el uso de tecnologías digitales. La investigación formaliza la formación de oficiales mediante la integración de soluciones tecnológicas, pedagógicas y de gestión, al tiempo que distingue este contexto específico de formación de los sistemas educativos generales o civiles. Desde el punto de vista metodológico, el estudio se basa en el análisis sistémico del proceso educativo y en la construcción de índices integrales y dependencias funcionales para evaluar la eficacia del aprendizaje. Los resultados indican que las plataformas digitales, los entornos de simulación, las herramientas analíticas y los sistemas algorítmicos transforman la organización de los planes de estudio, la gestión del aprendizaje, el desarrollo de competencias y las prácticas de evaluación. El modelo propuesto permite una evaluación más precisa de las actividades de los cadetes y la formación de trayectorias de aprendizaje individuales. Además, articula las competencias profesionales, de liderazgo y digitales, aclarando la relevancia educativa de la transformación digital en el marco de la formación militar superior.*

***PALABRAS CLAVE**: Transformación digital. Educación militar. Formación de oficiales. Tecnologías de simulación. Competencias digitales.*

INTRODUCTION

Digital technologies are rapidly entering military training, but educational programs are not keeping up with these changes. Armed Forces officers are increasingly working with huge data sets and artificial intelligence (AI). Higher military educational institutions need to combine simulators, analytics, and algorithms in a single system, but existing approaches do not allow developing digital, professional, and management skills together. A gap is emerging: the technologies are there, but people do not always know how to use them. Therefore, new educational models are needed that combine work with data, algorithms, and practical situations (Shylo et al., 2022).

It is important to clarify the conceptual scope adopted in this article. The term “training” is used here to designate specialized professional preparation for operational military functions, whereas “education” refers to the broader pedagogical organization of learning processes, curriculum design, competency formation, assessment, and institutional management. Therefore, this study does not address general civilian education, nor does it claim that military training follows the same purposes, rules, or social conditions as traditional education systems. Its educational contribution is restricted to the analysis of higher military education as a specific form of professional formation, in which pedagogical principles are mobilized to organize learning, evaluate competencies, and guide the development of officers in a digital environment.

Operations are becoming more complex, automated systems are playing an increasingly important role, but most educational programs do not take this into account. There are no clear mechanisms for integrating AI, criteria for assessing digital competencies, and the connection with professional skills. Technologies are being introduced unsystematically. Therefore, a model of training for officers of the Armed Forces of Ukraine is needed that takes into account the interaction of humans with intelligent systems and allows for the evaluation of training results.

LITERATURE REVIEW

Studies by Bestyuk and Pokhnatiuk (2025) and Biggs (2025) show that digital tools increase the accuracy of assessment and allow for the construction of individual learning trajectories, but the problem of integrating different platforms into a single system remains due to the complexity of data synchronization. Chmyr et al. (2024) and Danilyan et al. (2023)

emphasize that digital platforms are changing the structure of the educational process, but there is a lack of unified indicators to assess the effectiveness of these changes.

Storey and Wagner (2025) and Kang and Lee (2025) analyze the possibilities of AI in military education: algorithms accelerate information processing, but there are problems with trust in the results due to insufficient training of teachers. Kapoula et al. (2026) and Joshi (2025) add that systems thinking and retraining of specialists are needed, but models that combine educational and management aspects are not yet available.

Kjeksrud et al. (2026) and Zhai et al. (2025) consider the use of virtual reality and AI: simulation environments improve the quality of training, but high costs and technical limitations require effective models for managing digital resources. Rashid et al. (2023) and Trofymenko et al. (2024) note that the impact of AI on the structure of operations changes the requirements for staff training, but the mechanisms for integrating these technologies into educational processes are insufficiently studied. Afina (2026) and Özbek and Erdem (2025) emphasize regulatory constraints and strategic risks that are hardly taken into account in educational programs.

The aim of the article is to improve the educational model for the professional training of Armed Forces of Ukraine (AFU) officers based on digital technologies. In this sense, the article should be read as a study situated at the intersection of professional military formation, digital learning environments, and competency-based curriculum management. This delimitation is necessary because the empirical object is not a general school or university context, but a highly regulated military training system whose objectives are linked to operational readiness and institutional defense demands.

MATERIALS AND METHODS

The research methodology is based on a systems approach to analyzing the digital transformation of military education. Formalized models are used for the objective assessment of learning effectiveness. The initial stage involves structuring the educational process into four functional levels. These include infrastructure, pedagogical, managerial, and competency blocks. Each level contains a specific set of parameters of state and development dynamics. All indicators are unified on a single scale for further correct aggregation of data.

The analytical part is based on an integral model of the functioning of digital military education. This tool evaluates the coherence of individual components of the studied system.

The calculation of the final indicator is carried out through weighted indices of the contribution of each level. The weighting coefficients reflect the significance of components in the overall structure of AFU officer training. The functional evaluation model integrates professional, leadership, and digital competencies of a specialist. Additionally, the intensity of the use of artificial intelligence technologies and existing practical experience are taken into account. The model reflects the complex nature of training and the interconnection between its elements. The transformation process is studied through a step-by-step algorithm from system audit to result evaluation. Each step is characterized by its own quantitative performance indicators.

RESULTS

Part 1. Practical transformation of the officer training system in the digital environment

Practical changes in the training of officers of the Armed Forces of Ukraine in the digital environment occur through the transformation of the structure of the educational process, the logic of interaction and decision-making tools. The educational units of military universities of Ukraine are moving from disparate resources to integrated digital platforms that combine training, simulation and analytics. A modular architecture of the educational environment is being implemented, which involves the synchronization of LMS platforms, simulation systems (reproducing combat scenarios with variable parameters) and analytical tools (Trofymenko et al., 2024). The interaction of modules ensures the continuity of training and reduces the gap between theory and practice (NATO DEEP, 2025).

With the change in architecture, there is a transition to analytically oriented management: data on cadet activity, test results and actions in simulations are processed in real time, which allows you to adjust scenarios and identify weaknesses. The cadet works with digital scenarios that change depending on his actions (Găină, 2025). The integration of AI shifts the focus of assessment from the result to the analysis of the process, and adaptive systems build individual learning trajectories (Chmyr et al., 2024; Mishra, 2025). Practical training formats are also changing: war games are moving to a digital format, red-teeming is implemented through simulation models of the enemy's actions, and scenario modeling integrates geographical, technical and behavioral parameters (Özbek & Erdem, 2025). Problem-oriented cases are formed on the basis of real situations and do not have a single solution (Kjeksrud et al., 2026; Tran and Tran, 2026).

Part 2. A Model of Training Officers of a New Type in the Context of AI and Digital Warfare

The competency model of an officer of the Armed Forces of Ukraine combines professional, leadership and digital skills. Assessment moves to quantitative models through indicators of reaction speed, accuracy of decisions and work with data.

The educational process becomes multi-level: basic level (digital literacy), operational (interaction with algorithms) and strategic (analytical models). The cadet sequentially moves from simple tasks to managing complex systems (Joshi, 2025), with assessment at each stage (Table 1). At the final stage, work with complex scenarios based on large arrays of analytical data (Figure 1). The need to control autonomous systems is growing: the officer must evaluate the results of the algorithms and monitor their errors.

Table 1.

Comparison of Characteristics of Training Levels of Officers of the Armed Forces of Ukraine According to a Multi-Level Model

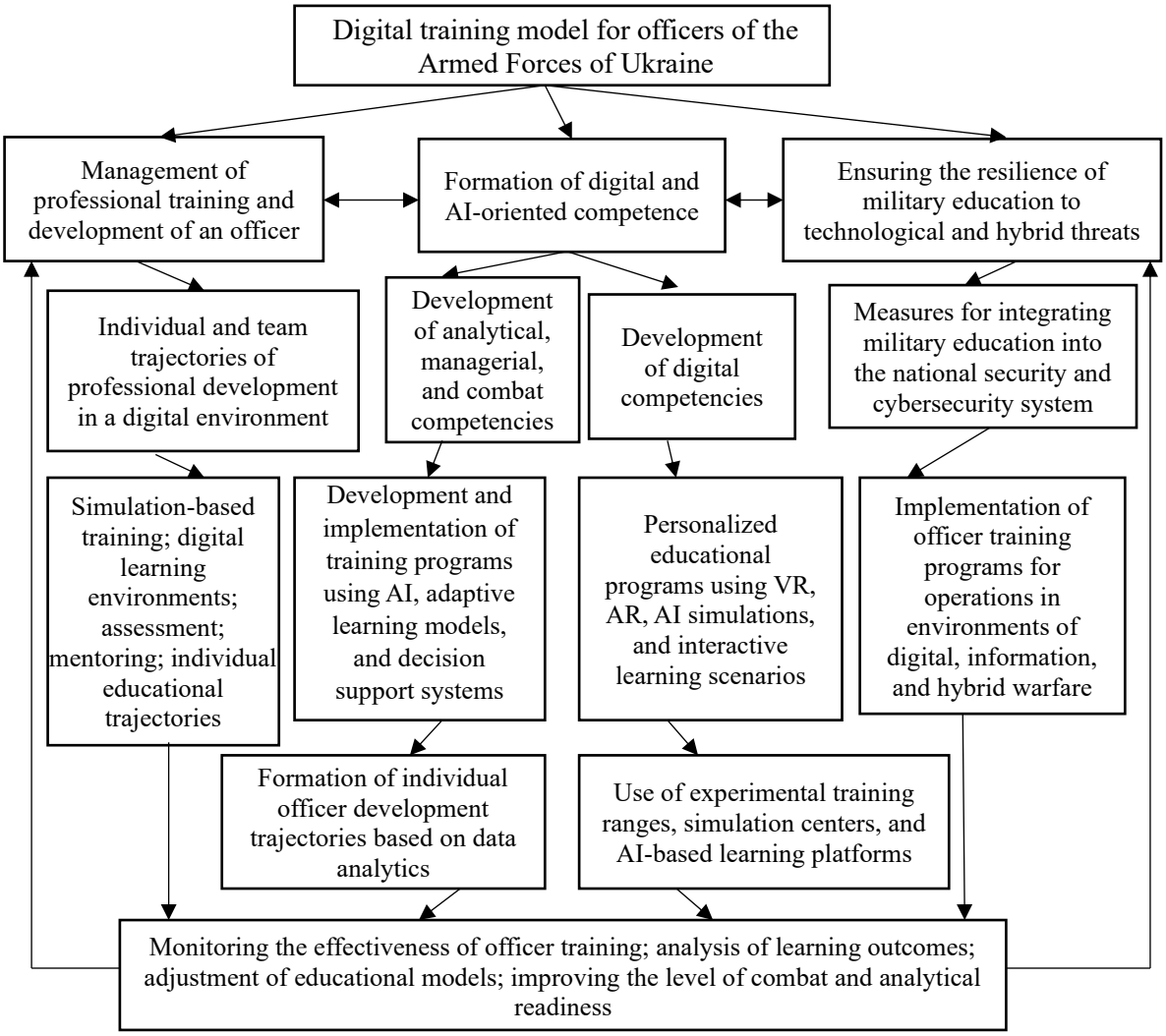
No.	Level	Main Skills	Tools	Assessment Type	Learning Outcome
1	basic	digital literacy	LMS	testing	basic knowledge
2	basic	information handling	online platforms	monitoring	data processing
3	operational	interaction with ai	simulations	analysis	accuracy of actions
4	operational	decision-making	algorithms	case studies	efficiency
5	strategic	systems thinking	analytics	modeling	forecasting
6	strategic	process management	ai-systems	complex assessment	optimization
7	integrated	coordination	digital environments	combined	effectiveness

Note. Constructed based on Makedon et al. (2025).

The use of autonomous systems, understandably, requires the formation of ethical norms. An officer of the Ukrainian army now evaluates not only the effectiveness of a decision, but also the extent to which it complies with established rules. This includes analyzing possible consequences and determining the admissibility of certain actions. Such an approach, in fact, forms responsibility for the use of technologies. Ethical aspects are gradually being integrated into training scenarios (Afina, 2026).

Figure 1.

Integrated Educational Model of Professional Training of Officers of the Armed Forces of Ukraine Based on Digital Technologies



Note. Developed by the authors.

Military institutions are implementing management systems that take into account data on cadet activities, which becomes the basis for оперативне (operational) adjustment of training and improvement (Table 2) (Rodikov et al., 2025).

Table 2.

Assessment of the Impact of Ethical and Managerial Control on the Effectiveness of Training of Officers of the Armed Forces of Ukraine in the "Human–AI" Coordinates

No.	System component	Type of control	Indicator (unit)	Mean Value	Coefficient of variation (%)	Integral Effect (0–1)
1	Algorithmic decisions	automated	accuracy (%)	86	5.2	0.82
2	Operator behavior	cognitive	errors (units)	3.4	12.1	0.71
3	AI control	combined	deviation (%)	9	8.7	0.76
4	Decision-making	expert	time (sec.)	42	10.3	0.79
5	Ethical assessment	normative	compliance (%)	81	6.4	0.74
6	Process management	analytical	efficiency (%)	84	5.9	0.80
7	System integration	systemic	consistency (%)	78	7.6	0.73

Note. Constructed based on Liu e Bates (2025) and Wu et al. (2025).

The systematization of training models shows that the effectiveness of education depends on the integration of competencies, technologies, and methods. The digital environment forms a new structure of the educational process, where decisions are made based on data.

Part 3

The proposed integrated educational model of professional training of officers of the Armed Forces of Ukraine based on digital technologies describes the interconnection between the main levels of the system. Each level has quantitative parameters that are subject to measurement and control. To assess the integral result, an indicator of the effectiveness of the digital educational system is introduced (detailed internal indicators are provided in Appendix).

$$DME = \sqrt[\alpha_1+\alpha_2+\alpha_3+\alpha_4]{I^{\alpha_1} \cdot P^{\alpha_2} \cdot M^{\alpha_3} \cdot K^{\alpha_4}} \cdot (1)$$

Where: DME – integral index of digital military education; I – index of infrastructural support; P – index of pedagogical adaptation; M – index of management of educational processes; K – index of formed competencies; α_1–α_4 – weighting coefficients of the influence of components.

The model takes into account the dependence between components: a decrease in one parameter limits the overall result even with high values of others. The formation of an integrated educational model for training officers of the Armed Forces of Ukraine based on digital technologies involves taking into account different groups of competencies and their interaction with the technological environment (Makedon et al., 2025).

The level of training is not determined by individual indicators but is formed as a function of several variables that interact with each other.

$$“ O = \frac{C_p \cdot \beta_1 + C_l \cdot \beta_2 + C_d \cdot \beta_3 + AI_{int} \cdot \beta_4 + Exp \cdot \beta_5}{\beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5}. ” \quad (2)$$

Where: O – the integral level of officer training; C_p – indicator of professional competencies; C_l – indicator of leadership competencies; C_d – indicator of digital competencies; AI_{int} – level of artificial intelligence integration; Exp – practical experience; β_1–β_5 – weighting coefficients.

The use of a weighted additive model allows you to adapt the structure of training depending on priorities. The development of competencies occurs through a system of guided educational influences, which are formed on the basis of data on the activities of cadets. The choice of tools depends on the type of competence and its role in the overall structure of training For evaluating the effectiveness of implementation, an aggregated indicator is introduced:

$$“ E_{impl} = \frac{\sum_{i=1}^{n} R_i \cdot w_i}{\sum_{i=1}^{n} w_i}. ” \quad (3)$$

Where: E_{impl} – implementation effectiveness; R_i – result of the i-th stage; w_i – weighting coefficient of the stage; n – number of stages.

The model allows you to evaluate each stage separately and determine its contribution to the overall result, which allows you to quickly adjust the strategy. The digital transformation process includes several interconnected stages. The experiment was conducted at the Military Academy (Odesa). 64 second-year cadets (19–21 years old) participated, divided into a control (32) and an experimental (32) group without initial differences. The control group studied according to the traditional scheme (lectures, seminars, tests, paper cases, field exercises), the experimental group studied according to the author’s model (LMS with adaptive logic, AI modules, digital cases, VR scenarios, analytical panel). The experiment lasted 10 weeks (disciplines: “General tactics”, “Action management and unit tactics”, combined arms). Every week, the experimental group performed scenario tasks with variable conditions (AI changed the parameters). Evaluation by six indicators: accuracy of tactical decisions, average decision-making time, level of digital literacy, quality of coordination, resistance to errors, integral index of professional readiness. After the cycle, the following results were obtained.

The accuracy of tactical decisions in the control group increased from 68.4% to 75.1%, while in the experimental group—from 67.9% to 88.6%. The average decision-making time decreased in the control group by 9%, and in the experimental group—by 26%.

The level of digital literacy increased by 11% in the control group and by 34% in the group trained according to the author's model. The indicator of coordination of actions increased by 8% and 21%, respectively. Resistance to errors was checked by repeating the task after a sudden change in the scenario conditions: the control group maintained efficiency at 71%, and the experimental group reached 87%, which indicates higher adaptability to the dynamic environment and faster restructuring of action algorithms.

The integral indicator of professional readiness in the control group increased from 0.63 to 0.71, and in the experimental group - from 0.62 to 0.86. Additional analysis showed that the cadets of the experimental group made fewer repeated typical errors in subsequent attempts: the frequency of incorrect decisions decreased by 31%, while in the control group the corresponding decrease was 12%. Instructors also reported higher quality decision reasoning, better use of digital maps, and faster learning of new instructions. The results confirmed the effectiveness of the model: the combination of LMS, AI analytics, VR scenarios, and adaptive management provided higher scores across all criteria.

The greatest gains were recorded in decision-making speed, digital literacy, and the ability to operate in a changing environment.

DISCUSSION

The results are consistent with the findings of Bestyuk and Pokhnatiuk (2025) on the importance of digital platforms, but extend them through formalized interaction of components and integrated performance indicators. Unlike Biggs (2025), the proposed model takes into account the impact of AI on the decision-making structure and learning management. Compared to Chmyr et al. (2024) and Danilyan et al. (2023), which focus on the technological aspect, our approach covers the managerial level and quantitative measurement of results. The results confirm the ideas of Storey and Wagner (2025) on the impact of AI on decision accuracy, but unlike Kang and Lee (2025), they address the issue of competence integration through a functional model of combining different types of skills with the parameters of the technological environment. A parallel is traced with the findings of Kapoula et al. (2026) on the role of analytical tools, however, unlike Joshi (2025), our model allows us to quantitatively assess their

impact on learning outcomes. Kjeksrud et al. (2026) and Zhai et al. (2025) confirm the effectiveness of simulation technologies, and our study improves these results by including simulations in the performance indicators system. The novelty lies in building an integrated model of digital military education for the Armed Forces of Ukraine with formalized indices and functional dependencies. The contribution to the scientific discourse is the transition from descriptive models to analytical structures, which ensures the measurability of results. In practical terms, the proposed models create a basis for managing the digital transformation of military education through a system of indicators and calculated indices.

The proposed model is situated within the specific context of higher military education and the professional preparation of officers. Therefore, the study approaches military training as a specialized form of professional education, shaped by institutional hierarchies, operational requirements, ethical responsibilities, and specific accountability mechanisms. Rather than treating digital transformation only as a technological or operational issue, the model emphasizes its educational dimensions, including curriculum organization, learning analytics, assessment criteria, individual learning trajectories, and competency development. In this sense, the relevance of the model lies in its contribution to understanding how digital platforms, simulation environments, and AI-based tools can support structured learning processes in higher military institutions. The analysis also recognizes that the findings are context-dependent and should be interpreted in relation to the particular demands of officer education, rather than directly generalized to civilian higher education or basic education systems.

FINAL CONSIDERATIONS

Integrated digital environments significantly increase the effectiveness of training of officers of the Armed Forces of Ukraine through a combination of educational platforms, simulations and analytics. Cadets learn the material faster, perform tasks with variable scenarios more accurately, and adaptive algorithms shift assessment to the analysis of decision-making processes. The modern training model becomes multi-level, synthesizing digital, professional and leadership competencies. The officer increasingly performs the functions of monitoring and interpreting the results of the algorithms. Computational models formalize digital transformation through quantitative indicators, and the step-by-step implementation mechanism provides continuous monitoring of effectiveness. The results of the study confirm the need for a comprehensive approach to the modernization of military training in Ukraine.

The main conclusion of this study is that digital transformation in higher military education should not be understood merely as the incorporation of technological tools, but as the reorganization of the pedagogical and managerial architecture that supports officer formation. The findings indicate that LMS platforms, AI-supported analytics, VR scenarios, and adaptive assessment systems can improve decision-making speed, tactical accuracy, digital literacy, coordination, and adaptability when they are integrated into a coherent educational model. In this process, digital technologies become pedagogically meaningful when they are articulated with curriculum objectives, formative assessment, systematic feedback, and the progressive development of professional, leadership, and digital competencies.

At the same time, the effectiveness of the proposed model depends on clear criteria for competency assessment, adequate preparation of teachers and military instructors, ethical governance of AI-based tools, and continuous monitoring of learning outcomes. The results also show that algorithmic systems should not replace pedagogical judgment, but rather support instructors in identifying learning difficulties, adjusting training scenarios, and organizing individualized learning trajectories.

This study is limited by its specific institutional and military context. The experiment involved cadets from one military academy and focused on disciplines directly associated with operational and tactical training. Therefore, the proposed model should be interpreted as a contribution to specialized professional military education rather than as a general model for civilian higher education or basic education systems. Future research should compare different military institutions, examine long-term learning effects, investigate the preparation of instructors to work with AI-based systems, and assess the ethical and pedagogical consequences of using algorithmic tools in learning assessment.

The contribution of the study lies in demonstrating that digital transformation in higher military education requires the integration of technological infrastructure, curriculum organization, competency development, assessment criteria, and learning management. In this sense, the proposed model helps clarify how digital platforms, simulation environments, and AI-based tools can support structured learning processes in officer formation while preserving the specificity of the military educational context.

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APPENDIX

1. Formation of the infrastructure provision index:

$$I = \frac{\sum_{i=1}^{n} I_i \cdot w_i}{\sum_{i=1}^{n} w_i}. \quad (1)$$

Where: I – infrastructure provision index; I_i – partial infrastructure indicator; w_i – weighting coefficient of the indicator; n – number of parameters.

Partial indicators include: I_1 – level of LMS accessibility (% of active users); I_2 – coverage by simulation systems (% of training modules); I_3 – network bandwidth (Mbps); I_4 – level of platform integration (0–1); I_5 – system stability (% uptime without failures).

2. Formation of the pedagogical adaptation index:

$$I = \frac{\sum_{i=1}^{n} I_i \cdot w_i}{\sum_{i=1}^{n} w_i}. \quad (2)$$

Where: P – pedagogical adaptation index; P_j – indicators of learning adaptability; v_j – weighting coefficients; m – number of parameters.

The parameters include: P_1 – level of learning personalization (% of individual learning paths); P_2 – share of adaptive courses (%); P_3 – speed of content updating (days); P_4 – effectiveness of case-based methods (% of correct decisions); P_5 – level of cadet engagement (% activity).

3. Formation of the learning process management index:

$$I = \frac{\sum_{i=1}^{n} I_i \cdot w_i}{\sum_{i=1}^{n} w_i}. \quad (3)$$

Where: M – managerial efficiency index; M_k – partial management indicators; u_k – weighting coefficients; p – number of indicators.

The components of the index include: M_1 – accuracy of outcome prediction (%); M_2 – speed of managerial decision-making (sec.); M_3 – level of process automation (%); M_4 – consistency of decisions (0–1); M_5 – efficiency of resource utilization (%).

4. Formation of the index of developed competencies:

$$K = \frac{\sum_{l=1}^{q} K_l \cdot s_l}{\sum_{l=1}^{q} s_l}. \quad (4)$$

Where: K – competency formation index; K_l – indicators of training level; s_l – weighting coefficients; q – number of parameters.

The parameters include: K_1 – level of professional competencies (%); K_2 – level of leadership competencies (%); K_3 – level of digital competencies (%); K_4 – ability to work with AI (% of correct decisions); K_5 – stability of results (% repeatability).

Each index is formed as a weighted average that takes into account the different significance of the indicators. Normalization of parameters is carried out by bringing them to a scale from 0 to 1 or from 0 to 100%.

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