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Educational risks of AI integration into the training system for military specialists: Didactic and methodological aspects

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Abstract. The study was intended to carry out a comprehensive theoretical analysis of the pedagogical and methodological problems which are associated with the introduction of systems of artificial intelligence into training programmes in the defence sector. The research was based on a systematic comparison of strategic plans and regulatory acts in Ukraine, the USA and the Federal Republic of Germany, which was used for a comparison of approaches to the development of new professional competencies for the officer corps. The study found that the Ukrainian educational sector is developing according to a model of accelerated adaptation, where the implementation of a multi-level officer education system in line with North Atlantic Treaty Organization standards and the incorporation of extended distance learning courses have ensured the viability of institutions in combat conditions. The study determined that the USA prioritises the concept of rapid victory through flexible development cycles, whilst in Germany, the emphasis is on value-oriented engineering and independent programme validation. Statistical data confirmed the rapid growth of the AI-based military training market, which is set to reach USD 2.17 billion by 2030, in the context of a 24% increase in venture capital investment in specialist defence start-ups. The significance of the "human-in-the-loop" management principle has been identified, ensuring that responsibility for decision-making in complex tactical scenarios is maintained. The data revealed that the primary methodological issue remains the black-box effect, which, in the absence of algorithmic transparency, reduces staff confidence in technical tools. The practical significance of this is determined by its

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potential use by educational institutions to develop compulsory modules on query engineering, data verification and the ethical auditing of simulators

Keywords: digital literacy; educational environment; critical thinking; framework; gamification

Introduction

The rapid development of artificial intelligence technologies changed the structure of national security and defence and forced a radical rethink of teaching methods in the military training system. The integration of intelligent systems into the decision-making processes, strategic planning and the direct management of combat assets opens new opportunities, but also pedagogical risks. In the context of military conflicts, where the processing speed of large data sets is a decisive factor for survival, military education should not only guarantee the technical literacy but also foster the cognitive resilience of personnel in front of algorithmic errors and manipulation. The challenge of balancing technocratic progress with the preservation of human agency and the ethical responsibility of the officer corps is becoming a key challenge for military pedagogy, requiring an analysis of the methodological aspects of the introduction of artificial intelligence to the educational landscape of the world's leading nations.

O. Markiv *et al.* (2024) investigated the research and educational priorities for the use of artificial intelligence in building Ukraine's military capabilities in the context of a full-scale war. The researchers found that the effective development of the sector requires the creation of an open register of applied tasks, the prioritised introduction of dual master's programmes, and close cooperation between innovative institutions to achieve a technological advantage. The potential for using intelligent tools in secondary schools as a basis for training future personnel for wartime conditions was studied by O. Topuzov & S. Alekseeva (2024). The authors noted that the main tasks are the development of digital literacy through gamification and virtual assistants, which can be used for the maintenance of immersive learning even in the event of damage to the physical infrastructure of schools. Innovative approaches and the transformation of the educational process during hostilities were analysed by V. Gurkovsky *et al.* (2024), focusing on the integration of NATO planning standards. The researchers found that the use of virtual reality and simulators not only enhances the technical skills of multi-domain operations specialists but also influences the development of their psychological resilience to psychological stress. J. Spirnak & S. Antani (2024) explored the need to develop artificial intelligence training programmes for military medicine, considering learning algorithms as a means of improving treatment outcomes. The researchers concluded that the success of the reforms depends on the ability of new generations of military medical personnel to see machine systems not as a threat but as supportive colleagues in clinical workflows. M. Gaikwad & A. Choudhary (2025) studied the role of intelligent systems in the restructuring of military education through adaptive learning environments. The results showed that automating routine jobs allows more resources for mentoring but military professionals need to keep critical leadership skills in addition to technological skills. W. Combes (2025) explored effective human-machine interaction patterns in professional military education, separating command-and-control functions. The author identified three key conceptual vectors – strategic thinking, ethical responsibility and adaptive command – which should form the basis of the cognitive infrastructure of security sector institutions.

H. Putra & B. Mulyono (2024) investigated the paradoxical consequences of integrating

artificial intelligence into military education. The researchers found that the use of intelligent systems can enhance the effectiveness of training, personalise the learning experience and optimise data management processes. At the same time, the authors identified a range of critical threats, including risks of privacy breaches, the development of excessive dependence on technology among personnel, and the gradual decline of fundamental military skills. The findings of their work highlighted the need to develop a balanced educational policy that would take advantage of automation without compromising the basic combat readiness of future officers. N. Agarwala (2023) examined robotics and artificial intelligence as tools for reducing risks to personnel. The findings of the research demonstrated that, despite the economic benefits of reduced personnel costs, the implementation of such technologies requires the development of a comprehensive "roadmap" to maintain control over autonomous systems.

M. Mammadzada (2025) analysed the state of higher military education in Azerbaijan and its alignment with NATO and Turkish models. The author found that a shortage of personnel and logistical support is hindering the implementation of the interdisciplinary approaches required to train specialists in cybersecurity and leadership under new conditions. The revolutionary impact of large language models, in particular ChatGPT, on the military sphere and cyber defence was analysed by M. Hadi *et al.* (2023). The researchers found that the ability of algorithms to identify patterns in text radically changes human-computer interaction but requires constant updating of language mastery due to the vast volume of interactions. The impact of techno-nationalism on international cooperation in the field of defence artificial intelligence was investigated by D. Araya & M. King (2022). The findings confirmed that managing next-generation operations requires multilateral dialogue and expert discussion of states' intentions regarding the use of machine learning. A systematic review of the use of intelligent technologies in education in the Arab world was conducted by A. Alzahrani (2022), who studied strategies for responding to emergencies. The researcher found that the usefulness of a system is the dominant factor in its adoption, whilst the user-friendliness of interfaces in developing countries still requires improvement by developers.

Despite the wealth of academic literature, some gaps require further investigation. In particular, the specific pedagogical determinants of introducing artificial intelligence into the Ukrainian military education sector – covering the experience of intensive use of decision-support systems on the battlefield – remain understudied. There is also a lack of comparative analysis of the methodological risks of technocratic determinism in the training of specialists within different strategic cultures. The issue of didactic fragmentation within the Alliance requires further elaboration, as does the functional validation of ethical frameworks in the training of personnel in security and computer sciences. The study aimed to conduct a theoretical analysis of the pedagogical risks associated with the integration of artificial intelligence into the training system for military specialists, focusing on didactic and methodological aspects. To achieve this aim, the following tasks have been identified: to analyse the didactic transformation and pedagogical determinants of the introduction of artificial intelligence into Ukraine's military educational sphere; to investigate the evolution of military-technological didactics in the USA and Germany; to identify specific methodological tools and didactic frameworks for ensuring the reliability of intelligent systems in the training process.

Materials and Methods

The methodological framework of this theoretical study is based on a combination of general scientific and specialised research methods, which was used for a systematic analysis of the pedagogical risks associated with integrating artificial intelligence into the training system for

military specialists. Three representative jurisdictions were selected as the subject of the research, each demonstrating different strategies for introducing innovations into the military education sector: Ukraine (as a model of extreme digital transformation and the testing of technologies in conditions of full-scale war), the USA (as a representative of a model of forced technological adaptation and pragmatic dominance) and Germany (as a representative of an ethics-centred approach and value-oriented engineering). The choice of these countries was dictated by the need to compare didactic frameworks under conditions of varying degrees of security threats and levels of technological development. The first fundamental research tool was the formal-legal (dogmatic) method. It was applied to the analysis of the regulatory framework and strategic documents governing the principles of the use of intelligent systems in the defence and education sectors: Resolution of the Cabinet of Ministers of Ukraine No. 1556-r … (2021), materials of the U.S. Department of War (2020), U.S. Department of Defense (2022). In addition, the provisions of the EU Artificial Intelligence Act (n.d.) were analysed to identify current approaches to the regulation and implementation of artificial intelligence systems. The method was used to establish the structure of legislation on artificial intelligence, to define the limits of the procedural legitimacy of using automated systems in training, and to identify the regulatory factors that shape the qualification requirements for future officers. The key research methods employed were the comparative legal and comparative methods. These were used to compare institutional models, didactic strategies and methodological approaches to the training of military specialists in the countries under study: European Parliament (2025), NATO (2021; 2024b). In addition, information published by ArmyInform (2026) was used to supplement the analysis of current practices and developments in military education. The application of this method aimed to identify points of convergence in the architecture of educational platforms, establish specific national characteristics in approaches to "Mission Command", and assess the degree to which national programmes comply with NATO interoperability standards.

The systemic-structural method was applied to the analysis of organisational mechanisms for integrating artificial intelligence into military training. The study examined the structures and initiatives of the U.S. Department of Defense (2023) and NATO (2023; 2025). The aim of applying the method was to study the architecture of advanced distributed learning (ADL) systems, analyse the functioning of immersive AR/VR simulators, and establish the role of specialised innovation centres in ensuring the continuity of personnel professional development. A hermeneutic approach and content analysis were used to interpret the content of pedagogical concepts and ethical principles in UNESCO's international recommendations (2021; 2023), the European Defence Agency (2025). In addition, the provisions of ISO/IEC/IEEE 24748-7000:2022 (2022) were analysed to identify methodological and ethical requirements for the implementation of intelligent systems. The method was used to reveal the essence of concepts such as "automation bias", "cognitive atrophy" and "algorithm explainability", which were used for an assessment of the ideological underpinnings of ethical standards and their impact on the methodology for developing critical thinking in cadets.

A statistical method was employed to verify operational efficiency and market trends. The analysis covered quantitative data and industry forecasts (Stockholm International Peace Research Institute, 2025; Research and Markets, 2026). The method was used to measure the dynamics of the military AI training market, assess the volume of investment in defence start-ups, and determine the proportion of automated operations in training processes, which forms the basis for assessing the scale of potential teaching errors. The comprehensive combination of these methods ensured the reliability of the scientific conclusions.

Results

Didactic transformation and pedagogical determinants of the integration of artificial intelligence into Ukraine's military education sector. The integration of artificial intelligence (AI) technologies into the training system for military personnel in Ukraine is occurring amid a period of extreme digital transformation triggered by the Russian Federation's full-scale armed aggression. By 2026, Ukraine had become a military laboratory for the implementation of AI, where the latest developments are being tested directly on the battlefield (European Parliament, 2025). However, such rapid technological development creates specific pedagogical risks related to the didactic and methodological aspects of the professional training of future officers (Makarov, 2025). The didactic challenge includes the need to balance the rapid mastery of innovative tools with the preservation of a military leader's cognitive autonomy.

Educational science views AI as a system capable of mimicking human intellectual processes, such as the ability to reason, identify meanings and learn from experience (Clement, 2024). For military education, this means a shift towards training systems that can observe, evaluate and make decisions at a level that previously required exclusively human expertise. According to international approaches, AI is a machine-centred system that, based on the input data received, concludes how to generate outputs in the form of predictions or recommendations that affect the real world. As far as 2021, the regulatory framework for this process was developed by the Resolution of the Cabinet of Ministers of Ukraine No. 1556-r ... (2021), which defined defence and education as priority areas of state policy. The main problem in accordance with this document is low level of digital literacy and absence of special educational programmes meeting modern requirements. The concept revealed several problems in the national training system: low level of mathematical competence among school leavers, which hinders further research in the field of AI; absence of modern professional development programmes for teachers at military universities; and outdated data protection systems.

Another key factor is the lack of a unified ethical framework for the development of AI technologies across various areas of national security. In response, the state has set the task of promoting the competent use of AI across the entire population and bringing legislation into line with the standards of the OECD (2024). The concept envisages reforming the higher military education system by 2030, with the key objective being the creation of interdisciplinary master's programmes and the integration of leading online courses into the teaching process. The educational risks in this area are primarily cognitive in nature. The use of GenAI in the learning process may lead to the phenomenon of "writing without thinking". For a military specialist, whose work requires structured logical analysis under time pressure, delegating basic mental operations to algorithms poses a risk of "atrophy" in the ability to make independent decisions. UNESCO (2023) warns that over-reliance on AI tools could undermine the development of critical thinking skills and the ability to solve complex problems, which are essential for managing combat operations. The methodologists emphasised that GenAI can automate only lower levels of cognitive skills, providing "semi-finished" knowledge that creates an illusion of competence. In military education, this creates a risk of losing diversity of thought, as GenAI models inherently reproduce the dominant worldviews embedded in their training data and may ignore alternative or minority approaches to solving tactical problems. A methodological risk also includes the problem of AI-generated information – the ability of models to generate information that is factually incorrect but plausible (UNESCO, 2023). In the context of military tactics or strategic planning, acting on such advice from AI-based decision-support systems could have fatal consequences. Researchers emphasise that GenAI lacks awareness of the real world and social relations, and merely statistically predicts the next elements in a data chain. Consequently, the

approach to military training in Ukraine in 2025-2026 is shifting from the mere accumulation of knowledge to teaching methods for verifying and critically evaluating AI output data.

A key stage in the transformation of the training system in Ukraine was the institutional audit of higher military education conducted by a NATO expert group in 2025 (ArmyInform, 2026). The main objective of the audit was to confirm progress in bringing training into line with NATO (2022) standards, in particular, the introduction of a multi-level system of professional military education (L-1 to L-5) for officers and the reform of training for non-commissioned officers. The experts noted the successful integration of NATO planning and decision-making standards (TLP, MDMP, OPP) into the curricula of Ukrainian military universities. In particular, Ukraine has successfully implemented the principles of "Mission Command" into its combat training programme, which is essential for interoperability with Alliance forces. The audit also confirmed the recognition of military professions within the National Qualifications Framework and the raising of English language proficiency requirements in accordance with STANAG 6001. The training model is focused on developing an "AI-ready workforce" – personnel who not only possess technical skills but also comprehend the strategic implications of using AI in multi-domain operations. However, the transition to NATO (2021) standards requires not only organisational changes but also adherence to the Principles of Responsible Use. NATO's updated Strategy (2024b) on AI identifies six key principles: legality, accountability, explainability, reliability, controllability and mitigation of bias. For Ukrainian military educators, this means the need to develop teaching methods that explain to cadets (students) not only how AI works, but also the ethical standards by which it must operate. It highlights in particular the principle of the "human-in-the-loop", which ensures that responsibility for the use of force is never lost by the human (NATO, 2021). The principle of "Explainability and Traceability" requires transparency in the training processes: cadets should be aware of the sources upon which the decision of the AI is based and the ways by which it was verified. The "controllability" of the system means that it can be shut down in case of unintended behaviour. Future officers need to have the skills to stress-test algorithms.

Furthermore, NATO (2024b) highlights the risk of AI being misused by state and non-state actors for disinformation and the manipulation of public opinion, which adds a methodological dimension to the training of strategic communications specialists. The didactic aspect also covers the implementation of ADL (NATO, 2025). As of October 2025, the NATO DEEP eAcademy course catalogue contains specialised modules in Ukrainian, including training on cyber defence (ADL 076), resource management (ADL 116) and the fundamentals of integrity education (ADL 336). The ADL 076 course provides basic terminology and teaches how to recognise social engineering and phishing, which form the basis of a military professional's digital hygiene. The RMEP programme (ADL 116) explains the Alliance's complex financial systems, ensuring an awareness of the resource architecture. A new segment of courses, such as "Will It Work Online?", emphasises pedagogy, helping instructors to balance the relationship between teacher, student and content in a digital environment.

The use of such platforms implements the concept of "lifelong learning", but poses a challenge for teaching staff regarding the authenticity of knowledge assessment. The risk of academic misconduct using ChatGPT is forcing lecturers to rethink the design of assignments, shifting the focus towards practical exercises and simulation modelling of combat situations (UNESCO, 2023). Military training in Ukraine actively utilises simulation and cognitive modelling (Resolution of the…, 2021). AI in military games can be used to practise scenarios in an environment where mistakes are safe to make (NATO, 2025). However, this raises the risk of "algorithmic bias". If the data on which the model was trained contains

gender or ethnic stereotypes, AI may produce discriminatory recommendations. UNESCO (2021) emphasises that training in AI ethics must become a mandatory component of curricula at all levels to minimise these risks.

The educational landscape is also subject to economic and market forces (Research and Markets, 2026). The worldwide AI in military training market is projected to reach USD 2.17 billion by 2030. The key drivers are immersive AR and VR solutions and predictive mission planning systems. For Ukraine, this means the need to train not only users, but specialists who can manage the "collective intelligence" of humans and machines. European Defence Agency (2025) report on the dynamic field of operational design in the military sector is of great importance. Civilian training is usually done in stable conditions, but military AI tools have to constantly adjust to enemy manoeuvres. And so, there is a methodological problem, that training materials get outdated quickly. The European Parliament (2025) noted that the pace of innovation in the AI field is outstripping the development of legal and pedagogical doctrine. In Ukraine, this is being done by involving the IT industry in the development of qualification requirements and organising internships for lecturers at technology companies.

One particular risk is the psychological effect of AI on learners. Algorithms simulating human interaction may have unpredictable effects on cadets' emotional well-being and ability to social cohesion (UNESCO, 2023). In the course of teaching "human justice" and training in the Armed Forces of Ukraine, it is necessary to take into account that AI is an auxiliary tool, not a substitute for a mentor. The principle of "Responsibility and Accountability" requires instructors to clearly define the areas of responsibility. The developer is responsible for the technical soundness of the model, but the decisions that are made based on the data from the model are the sole responsibility of the person who has taken the advice. As part of the training of security and computer science specialists in Ukraine in 2026, the key focus is on "Bias Mitigation" – proactive steps to minimise unintentional bias in datasets. This requires cadets to master the nature of data and the methods used to process it. Teaching is evolving into a process of developing an "AI-ready workforce" – personnel who are aware of the limitations of the technology and are capable of operating in situations where AI becomes unavailable due to hostile interference or technical failures (NATO, 2024b). Table 1 summarises the pedagogical requirements and didactic tools for ensuring the reliability of AI in military education.

Table 1. *Functional matrix of pedagogical requirements and didactic tools for ensuring the reliability of AI systems in military education*

Area of integration	Key pedagogical principle (NATO/DoD/ UNESCO standards)	Educational risks and methodological limitations	Risk mitigation tools and certification (ADL/EDA/Concept)
Ethical and legal training	Legality and Liability: separation of actions of the algorithm and the commander's discretion	Dehumanisation of procedures; blurring of legal accountability for life-or-death decisions	ADL 336 courses (Integrity Education); implementation of the CEPEJ Code of Ethics in military games
Cognitive development	Explainability and Traceability: cadet's ability to explain the logic of AI	"Cognitive atrophy"; the phenomenon of "writing without thinking"; uncritical acceptance of GenAI "hallucinations"	The "Human-in-the-loop" methodology, using 67 intelligent templates from the eCase system to verify evidence
Technical assessment	Reliability and controllability: stable operation in areas without GPS coverage	"Digital rollback"; vulnerability to cyberattacks (phishing, social engineering); algorithmic data bias	ADL 076 training courses (Cyber Security); testing at AI Factories; the VAULTIS framework for data quality assessment

Table 1. *Continued*

Area of integration	Key pedagogical principle (NATO/DoD/ UNESCO standards)	Educational risks and methodological limitations	Risk mitigation tools and certification (ADL/EDA/Concept)
Operational management	Interoperability: compliance with STANAG 6001 and TLP/ MDMP standards	Technology gap; outdated curricula relative to the market (USD 2.17 billion)	NATO PME audit (L1-L5); immersive AR/VR simulators; predictive mission planning in accordance with the Tanzimat 2030 Strategy
The socio-psychological sphere	Reduction of bias: inclusivity and non-discrimination	Perpetuation of stereotypes (gender-based/ethnic); a decline in social cohesion within departments	Modules ADL 168/169 (Gender Issues); resocialisation based on AI analysis in accordance with the 2021 Concept

Note: *VAULTIS – Visible, Accessible, Understandable, Linked, Trustworthy, Interoperable, Secure*

Source: *compiled by the authors based on U.S. Department of War (2020), Resolution of the Cabinet of Ministers of Ukraine No. 1556-r … (2021), NATO (2021; 2023; 2024a; 2024b), UNESCO (2021; 2023), U.S. Department of Defense (2023), S. Clement (2024), European Parliament (2025), Stockholm International Peace Research Institute (2025), European Defence Agency (2025), European Commission (n.d.)*

An analysis of pedagogical requirements has revealed a systematic correlation between the technological complexity of AI and the need for cognitive autonomy among military professionals, with the central methodological challenge being to counter the risk of dehumanisation in decision-making through the implementation of the Alliance's ethical safeguards. The proposed toolkit for neutralising threats reshapes the very architecture of military training, shifting the focus from mechanical mastery of interfaces to the professional verification of algorithmic predictions using the eCase system's intelligent templates and specialised ADL modules. The implementation of the principles of explainability and traceability acts as a factor in preventing "cognitive atrophy", as cadets are compelled to construct independent logical arguments in parallel with those of the machine, ensuring the genuine realisation of the "human-in-the-loop" concept even in scenarios involving high-intensity combat operations. This approach transforms technical expertise from a narrow IT specialisation into a leadership competence, where system reliability is guaranteed not only by the software code but also by a culture of ethical auditing fostered within the officer corps and the ability to adaptively manage operations amid the dynamic shifts of a multi-domain conflict.

Thus, the basis of Ukraine's educational strategy for the introduction of AI into the military education and training system is the triad of digital literacy, ethical responsibility and cognitive resilience. The main educational goal remains the training of specialists who can critically evaluate the "stochastic patterns" of AI models and make autonomous decisions in critical situations, guided by the values of a democratic society and the norms of international humanitarian law. The application of AI in education is seen as a way to augment human capabilities, not to automate military intelligence.

The evolution of military-technological didactics in the US and Germany: Adaptation strategies, ethical validation and the risks of technocratic determinism. The reconfiguration of military training systems in the US and Germany by 2026 reflects the desire of leading Western nations to secure a technological advantage through the integration of AI into training and operational processes. However, the approaches of these countries differ: whilst the US focuses on a model of forced adaptation and "quick victory" through agile development cycles, Germany emphasises value-oriented design and the preservation of the "human element" in military management (European Parliament, 2025). Both jurisdictions view AI as a fundamental technology that will transform

the full spectrum of NATO's tasks (2021): from collective defence to crisis management. The US didactic strategy is based on documents from the U.S. Department of Defense (2022), which define AI as a means of maintaining military superiority. A key institutional step was the creation in 2021 of the Office of the Chief of Digital and Artificial Intelligence (CDAO), which consolidated previous initiatives, such as the JAIC, to scale solutions across the entire Pentagon. In November 2023, a document from the U.S. Department of Defense (2023) was published, which replaced previous plans and introduced a hierarchy of AI needs (from data quality (the foundation) to responsible AI (the pinnacle)).

For US military education, this means a shift towards a model of "upskilling and reskilling". Military universities and training centres are introducing targeted programmes to develop personnel capable of working with data as a product with clearly defined value and accountability (U.S. Department of Defense, 2023). However, the methodological risk in the US model is the conflict between the speed of implementation and the reliability of systems. The adoption of the "Agile" approach, where feedback between the developer and the user must take place within hours or days rather than years, presents a pedagogical challenge regarding the depth of cadets' mastery of the material. There is a risk that, in the context of training campaigns, military specialists will be focused on operating minimally viable products without a fundamental awareness of the internal logic of algorithms, which in real combat could cause "automation bias" – complete reliance on machine recommendations. The ethical component of specialist training in the US is governed by the AI Ethics Principles (U.S. Department of Defense, 2020), adopted in February 2020. These cover five areas: accountability, fairness, traceability, reliability and controllability. The pedagogical significance of these principles lies in fostering a culture of "sound judgement" among personnel. This requires US education not only to teach technical skills, but also to develop the cognitive ability to deactivate systems that exhibit unintended behaviour.

The German model of military training in the context of the "Zeitenwende" has demonstrated an approach in which AI is viewed primarily as a means of enhancing the Bundeswehr's survivability (European Parliament, 2025). Germany's National AI Strategy, updated in 2020, covers the defence sector; however, the 2023 Military Guidelines integrate AI into the context of digital transformation (Organisation for Economic Co-operation and Development, 2020). A key hub for innovation is the Bundeswehr's "Cyber Innovation Hub", which works with technology start-ups to solve tactical tasks in the form of an "artificial intelligence laboratory" (Clement, 2024). The didactic approach in Germany is based on the "Human-in-the-Loop" concept. In German military-pedagogical doctrine, this is viewed not merely as a technical safety protocol but as a fundamental ethical and didactic imperative that ensures the preservation of an officer's moral agency in the context of total digitalisation (Spriz, 2025). It involves the direct integration of human judgment into every decision-making cycle of an automated system, where the human acts not merely as the final verifier but as an active participant capable of interrupting or altering the algorithmic process at any point. From an educational perspective, this approach requires a shift from teaching cadets' basic skills in operating interfaces to developing a high level of "cognitive control capability", based on an awareness of the internal logic of AI and the ability to recognise when a machine is exceeding the limits of its competence.

In contrast to American pragmatism, German military pedagogy is based on "value-oriented engineering" and the ISO/IEC/IEEE 24748-7000:2022 (2022). This requires the introduction of a new professional role within military structures – the "Value Lead", whose task is to ensure that AI systems do not violate the ethical standards underpinning Germany's constitutional order during their development and operation. The methodological risk for the German training

system is related to the "black box" nature of AI models. The Bundeswehr is investigating the issue of "explainability" through the AI Observatory at Helmut Schmidt University (European Defence Agency, 2025). The pedagogical problem is that the level of trust in the tool drops if the operator does not know how the system arrived at a certain conclusion, thus negating the technological advantage. In response, German pedagogy is moving towards teaching the "verification of the validity" of input data, rather than merely following protocols. The European Union is a supranational regulatory body that impacts the German security sector through the EU Artificial Intelligence Act (n.d.). Although this act excludes military applications, it establishes a general framework for risk management (four levels) and transparency requirements, which the Bundeswehr is integrating into its training programmes to ensure "dual compliance" (civilian and military) (Clement, 2024). The 2025 "AI Continent Action Plan" (European Commission, n.d.), which provides for the establishment of an AI Skills Academy, the outcomes of which will form the basis for training technical personnel within the security forces, is also central.

A common challenge for the US and Germany is "didactic fragmentation" within the Alliance. Through the DIANA programme and the Innovation Fund, NATO (2024b) is seeking to standardise approaches to TEV&V (testing, evaluation, verification and validation). In 2024, it was emphasised that military test centres should determine the safety of applications in accordance with the Principles of Responsible Use, which requires instructors at military academies in both countries to use common assessment templates and simulation scenarios. The methodological aspect of training in the US and Germany also includes countering "digital poverty". As AI models are often trained on data from domestic countries, there is a risk that future officers will develop misconceptions about socio-cultural contexts in other regions. UNESCO (2023) warns that this could lead to the colonisation of standards and the marginalisation of alternative tactical solutions. For the US, which operates on a global scale, this creates a risk of strategic errors in the training of specialists for peacekeeping or coalition operations. Training methodology in the US actively utilises the "Maven" project and the "Replicator" initiative for training computer vision systems, which requires personnel to possess the skills to annotate large datasets (European Parliament, 2025). In Germany, however, the focus is shifting towards "resource-efficient learning" – the development of algor thms that require minimal amounts of data and energy, which is essential for the European context with its limited resources. A particular pedagogical risk is the "hallucinations" of large language models, which are becoming increasingly common tools in training environments. As OpenAI notes, even the most advanced models, such as GPT-4, are prone to inventing facts. In the training of staff officers in the US and Germany in 2025, compulsory "Prompt Engineering" modules were introduced, which teach not only how to formulate tasks but also how to verify references to non-existent regulations or combat orders generated by AI.

Systemic risk is also associated with the ability of adversaries, such as Russia, to use AI for disinformation and to undermine trust in military institutions within democratic societies (NATO, 2024b). This has led both countries to incorporate "cognitive security" training into their curricula. Military instructors teach cadets to recognise deepfakes and AI-driven information operations that could demoralise troops in times of conflict. The economic component of specialist training in the US and Germany is underpinned by the growth of the AI training market. In 2025, venture capital investment in European defence start-ups, such as Helsing (a partner of the Bundeswehr), rose by 24%, reaching USD 5.2 billion (European Parliament, 2025). In the US, similar processes are leading to the creation of the USD 500 billion "Stargate Project" ecosystem for the development of AI infrastructure, which includes training facilities. This poses a methodological challenge

of "technological debt" – outdated monolithic systems in military academies that cannot keep pace with updates to commercial AI solutions. To systematise the didactic requirements and operational standards that determine the direction of military training development in leading Western countries, a comparative analysis of AI reliability assurance tools has been developed (Table 2).

Table 2. *Methodological tools and didactic frameworks for the training of military specialists in the USA and Germany*

Comparison criteria	USA (CDAO model)	Federal Republic of Germany (the Bundeswehr model)	Educational significance for NATO
Basic data management standard	Implementation of the VAULTIS framework	Focus on "Data Sovereignty" and the protection of personal data following the General Data Protection Regulation (GDPR)	Development of skills in managing data as a strategic asset for the mission
Verification Methodology (TEV&V)	"Agile Feedback Loop": iterative testing between developers and end users	"Product-neutral evaluation": independent expert assessment of compliance with military safety standards	Standardisation of AI application certification procedures within the Alliance
Priority market segment	"Predictive Mission Planning": predictive planning and logistics systems	"Immersive AR/VR Training": immersive learning using virtual and augmented reality	Shift from static to dynamic training scenarios
Technical paradigm of learning	"MLOps": full model lifecycle automation	"Frugal AI": training on limited data sets to improve autonomy	Adaptation of specialists to conditions of limited resources and communication
Level of pedagogical autonomy	Transition to "Dynamic Delegation of Authority"	Retaining strict "Meaningful Human Control" at the points where life-or-death decisions are made	The division of responsibility between a person and an autonomous system

Source: *compiled by the authors based on analysis of U.S. Department of Defense (2023), NATO (2024b), European Defence Agency (2025), European Parliament (2025), Research and Markets (2026)*

An analysis of the data presented has shown that, as of 2026, training in the US is based on the implementation of the VAULTIS standard, which requires security and computer science professionals to master the information lifecycle (U.S. Department of Defense, 2023). This shifts the focus of training from the simple use of interfaces to the professional assessment of data quality at all stages – from collection to disposal. In contrast, the German training model emphasises independent validation, which is necessary to ensure military personnel's trust in systems operating in an electronic warfare environment (European Defence Agency, 2025).

The diversification of market-based solutions is of particular educational significance: whilst the US invests in predictive planning to accelerate the OODA loop, Germany focuses on immersive simulators to improve personnel survival rates (European Parliament, 2025). The comparison of the two approaches confirmed that modern military pedagogy is forced to solve the problem of "dynamic delegation of powers" when cadets are taught not only to operate machines, but also to determine the boundaries of AI autonomy depending on the degree of threat and the ethical complexity of the situation in the combat zone. Consequently, the integration of the technical MLOps paradigm with the concept of "lean AI" is becoming a key necessity for the creation of interoperable NATO forces able to operate effectively in multi-domain conflict environments. Overall, the comparison shows that the educational transformation in the US and Germany reflects the recognition of AI as a "force multiplier" that requires a new pedagogical paradigm. The US is building a flexible, iterative model for developing digital talent within the CDAO. Germany is

building a system of "trusted AI" through value-based engineering and ethical auditing. A key pedagogical risk for both countries remain the loss of "human agency" as a result of placing excessive trust in algorithms. The primary educational task is to train soldiers capable of acting autonomously in wartime conditions, exacerbated by AI-driven disinformation, and of maintaining control over technology at critical decision-making points that determine life and death.

Discussion

The findings of this study revealed that the integration of artificial intelligence into the training system for military specialists has evolved from a technical innovation into a pedagogical challenge, necessitating a fundamental review of the methodological foundations of teaching. The finding established during the study that institutional support was a decisive factor in successful digital transformation was corroborated in the study by A. Lakshmi *et al.* (2023). Based on the example of the United Arab Emirates, the authors demonstrated that digital technologies had a tangible impact on all aspects of higher education only when the organisation was active in the integration process, which was fully consistent with the findings of this study regarding the need for strategic management of AI implementation in military colleges. At the same time, the divergence identified in this study between the US, Germany and Ukraine regarding levels of technological maturity correlated with the conclusions of A. Bestyuk & S. Pokhnatiuk (2025). The researchers noted that although the integration of AI was strategically relevant for all the countries studied, its implementation was driven by different priorities: large-scale implementation in the US and the UK, as opposed to Germany's structured but measured approach. A separate aspect of the discussion was the issue of how AI technologies are perceived by military personnel. The functional matrix of pedagogical requirements developed in this study found its psychometric complement in the study by L. Hadlington *et al.* (2023). Researchers developed the "Attitudes toward AI in Defence" scale, which identified two key factors influencing attitudes towards the technology: "positive outcomes" and "negative consequences". The findings of this study regarding cognitive risks coincided with the public concerns identified by L. Hadlington *et al.*, highlighting the significance of the development of an "AI-ready workforce" not only through technical skills but also by addressing cadets' psychological attitudes. In the context of immersive learning, the findings of this study regarding the use of AR/VR simulators were compared with the position paper by G. Hwang & S. Chien (2022). The authors explored the potential of the metaverse in education, highlighting the role of AI as a facilitator of interaction, which aligns with the findings of this study regarding the need to use simulation modelling to reduce risks to personnel.

The methodological aspects of training specialists in security and computer science, analysed in this study, are theoretically underpinned by M. Khaleel *et al.* (2024). The researchers provided a comprehensive overview of AI techniques, from machine learning to computer vision, emphasising their role in enhancing decision-making performance. This study supplemented this analysis with the specifics of military didactics, where, according to J. Schraagen (2023), the responsible use of AI required consideration of the human factor and ergonomics. The author emphasised that the irony of automation continued to apply in the AI era, requiring increased moral situational awareness during system deployment. These arguments formed the basis for justifying the "Human-in-the-loop" principle, which in this study was identified as a key safeguard against didactic atrophy of thought. The issue of training military engineers, examined in this study through the lens of the 2021 concept, was discussed in comparison with the findings of V. Chmyr & N. Bhinder (2023). The researchers identified the main areas of AI application for developing the professional competencies of future engineering officers but noted a range of

challenges that hindered the transformation. This study confirmed the existence of these barriers, particularly regarding "technological debt" and the rapid obsolescence of training materials. Similarly, the successful experience of introducing game mechanics in Ukrainian higher education institutions, as described by I. Savina & N. Shostakivska (2025), demonstrated that gamification increased cadets' motivation and their ability to act in conditions of uncertainty. These findings were consistent with the results obtained in this study regarding the effectiveness of immersive simulators for practising tactical scenarios.

The issue of digital literacy among future teachers deserves attention in the discussion. N. Tytova & K. Mereniuk (2022) analysed the Ukrainian experience of teaching media literacy in the context of aggression, finding that state support and online platforms provided a sufficient level of preparation for students. This study extended this conclusion to the field of military education, where knowledge of methods to counter deepfakes and AI-generated disinformation has become part of "cognitive security". The importance of this approach was highlighted in a review by K. Enstad & A. Hagen (2026), who identified a lack of competencies of a junior officer across EU countries, making this study's contribution to the systematisation of NATO standards particularly relevant. The findings of this study on military training were compared with the study by J. Peacock *et al.* (2025). The authors demonstrated that preparation for future full-scale combat required medical personnel to be able to work under resource-constrained conditions using AI tools. Furthermore, F. Bahramnezhad *et al.* (2025) emphasised that the use of generative AI for scenario-based training can be used for the optimisation of resources but required oversight of data privacy. The impact of generative AI on academic integrity and cognitive skills was analysed in the context of studies by P. Kelly & H. Smith (2024). The researchers recommended avoiding extremes – ranging from a complete ban to uncritical acceptance – and incorporating "safeguards" into training programmes. This study put this pragmatic approach into practice by recommending a review of the design of tasks for cadets. Furthermore, A. Rashid *et al.* (2023) emphasised that AI enhanced the autonomy of combat systems, requiring officers to develop new skills in "strategic thinking". In the context of increased motivation, the findings of H. Putra *et al.* (2024) confirmed that the use of AI had a positive impact on learning effectiveness in a military environment, which was consistent with the effect of implementing ADL courses identified in this study.

Lastly, international experience of digitalisation, in particular the Latvian case described by M. Spridzans (2023), has shown that the pandemic served as a catalyst for preparing instructors for future trends. This correlated with the findings of this study regarding the adaptability of Ukrainian military higher education institutions during the war. An examination of the Chinese experience, as outlined by E. Kania (2022), revealed an alternative model of "intellectualised" warfare, which underscored the need for NATO to maintain pedagogical flexibility to counter adversaries employing different strategic logic. The role of AI as a strategic factor identified in this work is consistent with the research by G. Okropiridze & L. Zaalishvili (2025), who demonstrated that the integration of intelligent systems expands the cognitive, operational and logistical capabilities of the armed forces without a proportional increase in personnel numbers. The didactic transformation and transition to NATO standards described in this study are further explained in the comparative analysis by T. Libel & B. Ateş (2025). The researchers identified a consistent trend towards the convergence of professional military education with the academic standards of civilian universities, which has made it possible to dismantle the traditional military monopoly on the training of the officer corps. This confirmed the advisability of introducing a multi-tiered education system in Ukraine as a means of enhancing the professional legitimacy of the officer corps through the

diversification of training programmes and the involvement of external academic expertise under the auspices of the Joint Chiefs of Staff. Lastly, the methodological risks associated with the use of generative AI were detailed by A. Barros Junior *et al.* (2025). The researchers noted the irreversibility of AI use in military research but emphasised the need for "AI literacy" to neutralise algorithmic biases and content distortions. The results of their analysis confirmed the thesis of this study that the uncontrolled use of intelligent models without clear ethical boundaries poses direct threats to the cognitive development of future military leaders and may negatively impact the strategic stability of the state in the digital age. To summarise the above, the findings of this study demonstrated that global military pedagogy is at a point of bifurcation. A comparison of the results with the works of other authors confirmed the pattern of transition from the accumulation of knowledge to the development of the ability to verify algorithmic conclusions. The significance of the findings is determined by the identification of pedagogical safeguards that will ensure the preservation of human agency in the context of total digitalisation.

Conclusions

As a result of the theoretical research conducted, the set objective was achieved, and the research tasks concerning the analysis of pedagogical risks associated with the integration of artificial intelligence into the training system for military specialists were resolved. The study has established that global military didactics has shifted from a model of mere accumulation of knowledge to the development of the ability to verify algorithmic conclusions and preserve human agency in the context of the total digitalisation of the battlefield. The study established that the Ukrainian military education sector is undergoing a period of radical transformation, with artificial intelligence technologies being tested directly in combat conditions. The study established that the introduction of a multi-level system of professional military education for officers in accordance with NATO standards (levels L-1 to L-5) and the integration of Advanced Distributed Learning courses ensured adaptation of Ukrainian curricula to the requirements of multi-domain operations. Quantitative indicators highlight the importance of this process: the projected size of the global market for AI-based military training is set to reach USD 2.17 billion by 2030, whilst venture capital investment in relevant European start-ups has risen by 24% in the last year alone.

An important achievement of the transformation in Ukraine has been a change of the educational paradigm to the formation of cognitive resilience and ability to stress-test algorithms. The differences between the US and the German approach are analysed and it is concluded that inclusive training models are more effective. The study shows that the American model led by the Office of the Chief Digital Officer is based on the idea of a "quick win" and a flexible development cycle, while the German Bundeswehr is based on value-oriented engineering and independent system validation. The study confirmed that the introduction of the VAULTIS standard in the US and the establishment of the role of Chief Value Officer in Germany are important methodological safeguards against "automation bias". The results of the study show that without learning the ethical standards of interaction with machines, successful training of military personnel in 2026 will be impossible. The main pedagogical danger described in the research was the "black box" nature of algorithms that, in the absence of explainability, destroys the operator's confidence and causes errors in mission planning. The data confirmed the successful implementation of the "human-in-the-loop" principle as a fundamental requirement of the Alliance, that responsibility for the use of force had been retained. Areas for further research in this field could include the empirical verification of the effectiveness of specific didactic models for training military personnel to interact with autonomous systems under combat stress, the development of

national standards for assessing officers' cognitive readiness for the critical analysis of algorithmic recommendations, as well as research into the psychological and pedagogical mechanisms underlying the emergence of "automation bias" with a view to developing appropriate methodological tools for its prevention within Ukraine's military education system.

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Conflict of Interest

None.

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Педагогічні ризики інтеграції ШІ у систему підготовки військових фахівців: дидактичні та методичні аспекти

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Анотація. Метою проведеного дослідження став комплексний теоретичний аналіз дидактичних і методичних загроз, що виникають під час впровадження систем штучного інтелекту у навчальні програми оборонного сектору. Наукове вивчення ґрунтувалося на системному порівнянні стратегічних планів і нормативних актів України, США та Федеративної Республіки Німеччина, що дозволило зіставити підходи до формування нових професійних компетенцій офіцерського корпусу. У ході роботи встановлено, що український освітній простір розвивається за моделлю прискореної адаптації, де впровадження багаторівневої системи офіцерської освіти згідно зі стандартами Організації Північноатлантичного договору та залучення курсів розширеного дистанційного навчання забезпечили життєздатність інституцій у бойових умовах. Виявлено, що у США пріоритет надається концепції швидкої перемоги через гнучкі цикли розробки, тоді як у Німеччині акцент зміщено на ціннісно-орієнтовану інженерію та незалежну валідацію програм. Статистичні дані підтвердили стрімке зростання ринку військового навчання на базі штучного інтелекту, який досягне 2,17 млрд доларів до 2030 року, на тлі збільшення венчурних інвестицій у профільні оборонні стартапи на 24 %. Визначено значення принципу «людини в контурі» управління, що гарантує збереження відповідальності за прийняття рішень у складних тактичних сценаріях. Дані засвідчили, що основною методичною проблемою залишається ефект чорної скриньки, який за умови відсутності пояснюваності алгоритмів знижує рівень довіри особового складу до технічних інструментів. Практичне значення результатів полягає у можливості їх використання навчальними закладами для розробки обов'язкових модулів з інженерії запитів, верифікації даних та етичного аудиту симуляторів

Ключові слова: цифрова грамотність; освітній простір; критичне мислення; фреймворк; гейміфікація