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GLOBAL TRENDS IN WARGAMING RESEARCH IN MILITARY EDUCATION: BIBLIOMETRIC ANALYSIS OF SCOPUS DATASETS AND IMPLICATIONS FOR UKRAINE

Abstract. *The article presents a bibliometric analysis of wargaming research in the context of professional military education (PME) using a two-stage filtering strategy applied to the Scopus database. Two datasets were formed: a contextual dataset (query "military" AND "game*" AND "training OR education OR simulation", n=3,962, 2005–2026) covering the entire field of "military games" including mathematical game theory, and a target dataset (n=1,954, 1915–2026) from which game theory publications were excluded, retaining wargaming, military simulation, and serious games in the educational-training context. Visualization was performed using VOSviewer 1.6.20 with co-occurrence mapping of author keywords and country-level co-authorship analysis.*

The purpose of the study is to identify the thematic structure, chronological dynamics, and geography of global wargaming research and to determine Ukraine's position within this research landscape. Five network maps were constructed and analyzed. The contextual dataset map revealed that mathematical game theory dominates quantitatively (233 occurrences vs. wargaming – 27), necessitating two-stage filtering. After filtering, wargaming forms an autonomous cluster with military simulation (123 total occurrences), spatially separated from serious games, confirming its status as a distinct PME instrument. The convergence of AI methods and wargaming clusters on the research front corresponds to practical developments in NATO PME institutions (GenWar Lab, CGSC Vantage platform, Finnish edge AI model). Publication activity increased fivefold after 2020 – from 25 to 126 publications per year, peaking at 187 in 2024. The co-authorship map revealed that Ukraine is absent from the international collaboration network (threshold: 3 documents per country). This academic isolation corresponds with institutional findings: a content analysis of 79 Ukrainian PME regulatory acts identified wargaming terminology in only 8 documents (10 %), with none specifying methodology, standards, or facilitator qualifications; a comprehensive review of PME course catalogs (over 13,000 entries) found zero courses with a wargaming component.

The study's limitations include reliance on a single database (Scopus) and the exclusion of restricted military publications. Three recommendations are formulated: normative inclusion of wargaming in PME course catalogs; preparation of a facilitator cohort through NATO DEEP/NSO programs; and joint research projects with NATO wargaming centers as the mechanism for Ukraine's entry onto the Scopus co-authorship map.

Keywords: *wargaming; war games; bibliometric analysis; VOSviewer; Scopus; professional military education; artificial intelligence; NATO.*

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Глобальні тенденції досліджень wargaming у військовій освіті: бібліометричний аналіз масивів Scopus та імплікації для України

У статті подано бібліометричний аналіз досліджень вargeймінгу в контексті професійної військової освіти (ПВО) із застосуванням двоетапної стратегії фільтрації бази даних Scopus. Сформовано два масиви даних: контекстний (n=3962, 2005–2026), що охоплює всю сферу «військових ігор», виключно з математичною теорією ігор, і цільовий (n=1954, 1915–2026), з якого вилучено публікації з теорії ігор та залишено вargeймінг, військову симуляцію та серйозні ігри в освітньо-тренувальному контексті. Візуалізація виконана у VOSviewer 1.6.20 з картуванням спільної зустрічальності авторських ключових слів та аналізом співавторства на рівнях країни.

Мета дослідження – виявити тематичну структуру, хронологічну динаміку та географію глобальних досліджень вargeймінгу, а також визначити місце (позицію) України в цьому дослідницькому ландшафті.

Побудовано та проаналізовано п'ять мережевих карт. Карта контекстного масиву показала кількаразове домінування математичної теорії ігор (233 згадування проти 27 для вargeймінгу), що зумовило потребу в двоетапній фільтрації. Після фільтрації вargeймінг створює автономний кластер разом із військовою симуляцією (123 згадування сумарно), просторово відокремлений від серйозних ігор, що підтверджує його статус самостійного інструменту ПВО. Конвергенція кластерів методів ШІ та вargeймінгу на фронті досліджень відповідає практичним напрацюванням в установах ПВО НАТО (GenWar Lab, платформа CGSC Vantage, фінська модель edge-AI). Публікаційна активність зросла після 2020 року вп'ятеро – з 25 до 126 публікацій на рік, із піком у 187 публікацій у 2024 році. Карта співавторства засвідчила вихід України в мережу міжнародної наукової співпраці (поріг – 3 документи на країну). Академічна ізольованість корелює з інституційними результатами: контент-аналіз 79 українських нормативних актів з ПВО виявив термінологію вargeймінгу лише у 8 документах (10 %), причому в жодному не конкретизовано методологію, стандарти чи кваліфікаційні вимоги до викладача; суцільний огляд каталогів курсів ПВО (понад 13 000 позицій) не виявив жодного курсу з компонентом вargeймінгу.

Обмеження дослідження – операція на одну базу даних (Scopus) та вимкнення публікацій з обмеженим військовим доступом. Сформульовано три рекомендації: нормативне включення вargeймінгу до каталогів курсів ПВО; підготовка когорти фасілітаторів через програми NATO DEEP/NSO; спільні дослідницькі проекти з вargeймінговими центрами НАТО як механізм появи України на карті співавторства Scopus.

Ключові слова: *військові ігри; військові ігри; бібліометричний аналіз; VOSviewer; Scopus; професійна військова освіта; штучний інтелект; НАТО.*

Problem statement. Since 2022, NATO has been systematically institutionalizing wargaming as an instrument of professional military education (PME). The NATO Wargaming Handbook [1], the annual Wargaming Initiative for NATO conferences (WIN, 2022–2025), and courses at NATO School Oberammergau together form an institutional ecosystem that spans educational wargaming from the tactical to the strategic level. In parallel, generative artificial intelligence (AI) is transforming wargaming at PME institutions across Allied nations: the U.S. Army

Command and General Staff College plans to standardize AI-assisted wargaming beginning in the 2026–2027 academic year [18].

The term «professional military education» (PME) is used throughout this article in the meaning established by NATO Bi-SC Directive 075-007: the structured education of officers at intermediate and senior levels, as distinct from initial officer training and short-term courses. In Ukrainian practice, PME corresponds to the educational programmes of higher military educational institutions (HMEIs) at the operational-strategic level.

This growing institutional attention has been accompanied by an exponential rise in scholarly research. Yet the structure of this research field – its thematic clusters, chronological dynamics, and geography – remains largely unexamined. In particular, no study has determined where Ukraine stands within this landscape. Ukraine wages a full-scale defensive war and seeks NATO integration. At the same time, its PME system recognizes wargaming doctrinally but has not operationalized it: a content analysis of 79 regulatory acts conducted by the authors identified wargaming terminology in only 8 documents (10 %), while none of the PME course catalogues (over 13,000 entries in total) contains a single course with a wargaming component. Bibliometric analysis provides the means to objectively determine this position and to identify thematic reference points for bridging the gap.

Analysis of recent research and publications. The conceptual framework for wargaming in PME is shaped by the NATO Wargaming Handbook [1], monographs by Perla [2] and Appleget, Burks, and Cameron [3], and Curry's review [4] in Simulation & Gaming. The institutional dimension is examined in a GAO report [5], which identified fragmentation of wargaming programmes within the U.S. Department of Defense. Bojor (2024) [6] recommended introducing a dedicated war games discipline into higher military education curricula and extending this approach to army units for continuous professional development. Davis and Bracken [7] proposed a framework for applying AI to wargaming. A special issue of the Scandinavian Journal of Military Studies (2022) presented empirical evidence of wargaming effectiveness in Scandinavian PME: Roennfeldt, Helgesen, and Reutz [8], Enstad [9], Hagen [10].

Three concepts central to this analysis require delineation. Wargaming, as defined in the NATO Wargaming Handbook [1], is a structured exercise in which participants make decisions within a scenario governed by three constitutive elements: player decisions that drive the narrative, friction that introduces uncertainty, and adjudication that resolves outcomes. Serious games, a term introduced by Abt [20] to denote games designed for purposes beyond entertainment, constitute a broader category that encompasses educational simulations, gamified training modules, and game-based learning platforms; unlike wargaming, they do not necessarily involve adversarial decision-making or adjudicated friction. Military simulation refers to computational models that replicate aspects of military operations for training or analysis, ranging from constructive (entity-level) to virtual (human-in-the-loop) and live formats [2]. These three domains overlap but are not synonymous; the bibliometric analysis below confirms their structural separation within the Scopus literature.

Bibliometric studies of wargaming are virtually nonexistent. Van Eck and Waltman [11] developed VOSviewer – a tool widely used for mapping scientific

fields – yet its application to the analysis of wargaming research has not been documented. Bondarenko and Hupalo [12] conducted a bibliometric analysis of AI integration in military education (n=266, Scopus), identifying three development phases and the absence of wargaming as a distinct cluster within that dataset. Hurochkina, Bondarenko, and Szapiro [13] analysed the opportunities and risks of implementing AI technologies in the military domain. A systematic bibliometric analysis of wargaming itself in the PME context, employing two-stage filtering and visualization, has not been undertaken.

The purpose of the article is to determine the thematic structure, chronological dynamics, and geography of global wargaming research in military education; to identify Ukraine's position; and to formulate implications for the PME system.

Bibliometric analysis methodology. A two-stage strategy was employed. In the first stage, a contextual dataset was formed using a broad Scopus query («military» AND «game*» AND «training OR education OR simulation», n=3,962, 2005–2026), covering the entire field of «military games», including mathematical game theory. In the second stage, a target dataset was constructed (n=1,954, 1915–2026) by excluding publications from the game theory domain (Nash equilibrium, differential games, evolutionary games) and retaining wargaming, military simulation, and serious games in the educational and training context. Visualization was performed in VOSviewer 1.6.20 [11] using the co-occurrence method for author keywords with a threshold of 5 occurrences for the contextual dataset and 10 for the target dataset. The international co-authorship map was constructed with a threshold of 3 documents per country. The two-stage strategy makes it possible to distinguish the wargaming discourse from the broader «gaming» context and to reveal structural characteristics that remain invisible when analysing a single dataset.

Scopus was selected as the sole data source for three reasons: it is the largest abstract and citation database (over 49,000 active journal titles), VOSviewer is natively optimized for Scopus export formats, and single-database designs remain standard in bibliometric research where the objective is thematic mapping rather than exhaustive coverage [11]. This choice entails a limitation: departmental publications, restricted military reports, and journals indexed exclusively in Web of Science fall outside the analysis. The term «global» in the article title refers to the geographic scope of the dataset (publications from 48 countries) rather than a claim of exhaustive coverage.

Presentation of the main material.

1. Contextual dataset: the structure of the «military games» field.

The network map of the contextual dataset (Fig. 1) reveals five thematic clusters. The right sector is occupied by the dominant mathematical game theory cluster (game theory – 233 occurrences, Nash equilibrium, differential games, Q-learning), associated predominantly with optimization problems in network security. The left sector contains a geopolitical-conflict cluster (war, conflict, geopolitics, diplomacy, China, Ukraine), while the central-lower zone concentrates the educational discourse: simulation (90), serious games (93), wargaming (27), training (54). The wargaming node does not form a dense core of its own – it is positioned at the intersection of three domains, indicating the interdisciplinary diffuseness of the concept within the broad dataset.

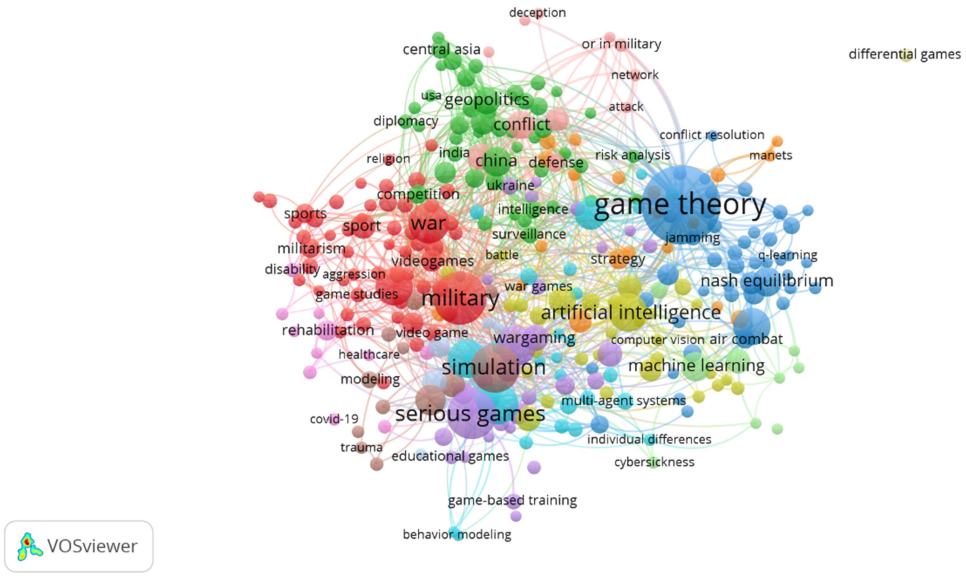

Fig. 1. Co-occurrence network map of author keywords in the contextual Scopus dataset (n=3,962). VOSviewer, network visualization.

The temporal map (Fig. 2) reveals the chronology.

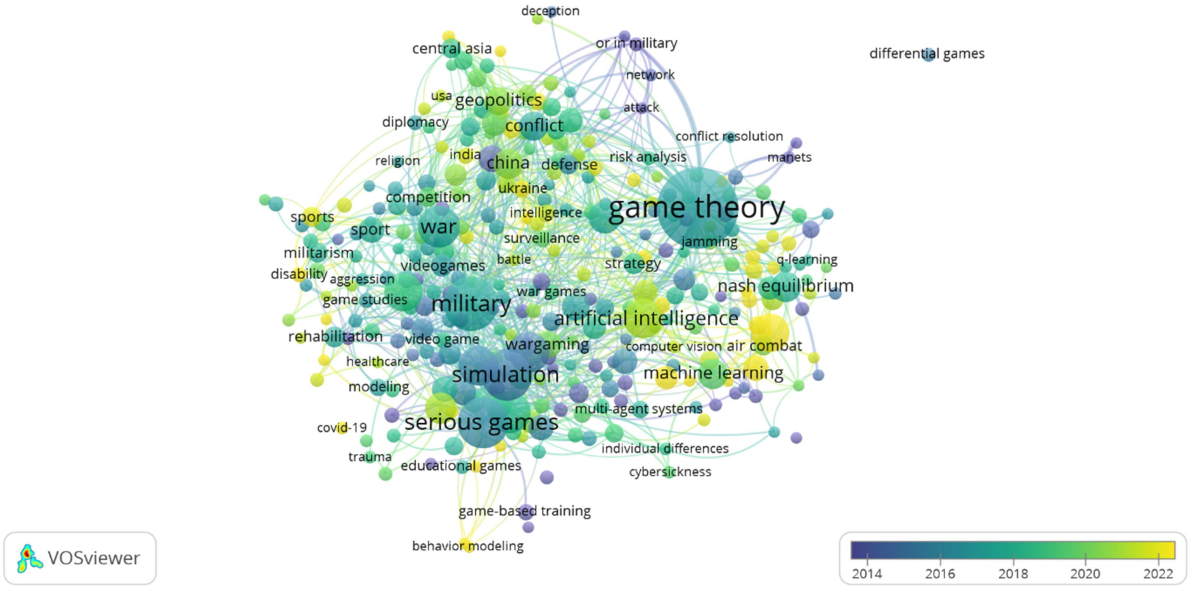

Fig. 2. Temporal co-occurrence map of the contextual dataset. VOSviewer, overlay visualization (scale 2014–2022).

The oldest topics (~2014–2016) belong to game theory. Wargaming falls within the middle zone (~2017–2019), corresponding to the onset of the «wargaming renaissance» in Western defence establishments [4]. The most recent nodes (~2020–2022) concentrate in two directions: AI methods (machine learning, multi-agent systems) and educational games (serious games, game-based learning). The overall trajectory runs from wargaming as an isolated practice toward integration with AI and serious games pedagogy.

A comparison of the two maps yields a methodological conclusion: queries for

«military games» return a dataset in which game theory dominates quantitatively (233 occurrences versus wargaming – 27). A researcher analysing wargaming without filtering risks constructing a map in which mathematical optimization problems mask the educational and training discourse. This justifies the need for the second stage.

2. Target dataset: wargaming in the PME context.

Once game theory is excluded, the thematic architecture assumes a different configuration (Fig. 3).

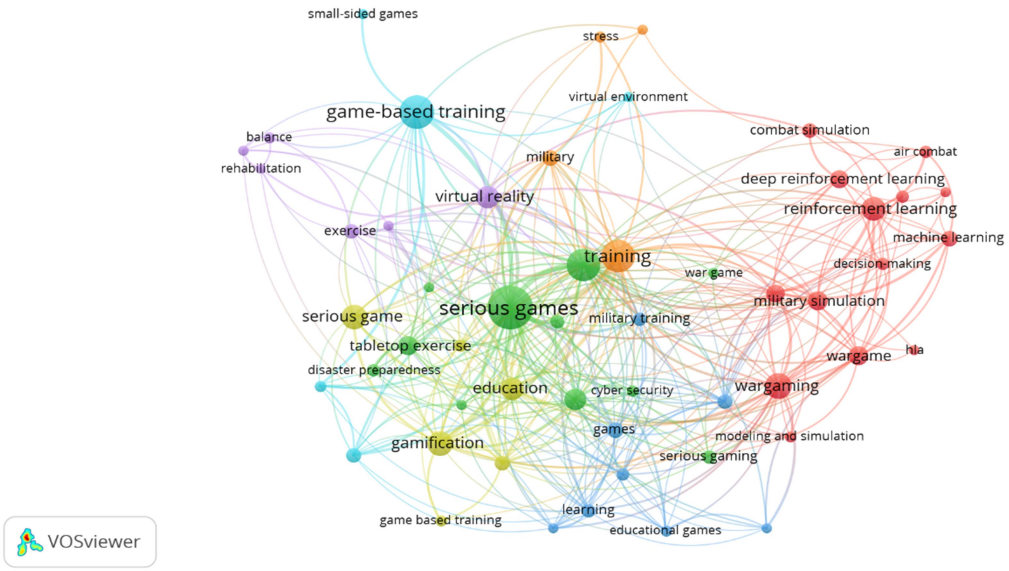

Fig. 3. Co-occurrence network map of the target Scopus dataset (n=1,954, game theory excluded). VOSviewer, network visualization. 54 nodes, 7 clusters, threshold — 10 occurrences.

The target dataset (n=1,954) is distributed across 7 clusters comprising 54 nodes (Table 1).

Table 1

Thematic clusters of the target Scopus dataset (n=1,954)

Cluster	Colour	Keywords (occurrences)	Interpretation
1. Educational-training	Green	serious games (178), game-based training (108), training (101), tabletop exercises (35)	Pedagogical focus of PME
2. Military-simulation	Red	wargaming (65), war game (36), military simulation (35), combat simulation (22), kriegsspiel (22)	Wargaming proper: 123 occurrences combined
3. AI methods	Yellow	reinforcement learning (54), deep RL (32), machine learning (23), air combat (16)	AI in military modelling
4. Immersive learning	Teal	virtual reality (49), game-based learning (43), virtual environment (28)	ETEE subcategory UA-1227 "Modelling and Simulation"
5. Cybersecurity	Purple	cyber security (31), network security (22), intrusion detection (18)	Infrastructure protection
6. Autonomous systems	Orange	unmanned systems (24), swarm (19), multi-agent (17)	Integration with uncrewed platforms
7. Assessment and analytics	Grey	assessment (21), learning analytics (15), after action review (12)	Measuring training effectiveness

Source: compiled by the authors based on bibliometric analysis of Scopus data, VOSviewer.

The spatial distance between clusters 1 and 2 indicates that wargaming and serious games (in the sense of Abt [20]: games designed for purposes beyond entertainment), despite sharing a common subject area, belong to distinct research communities with different traditions and publication channels. For the PME system, this means that serious games and wargaming require different implementation strategies and different specialists.

Cluster 3 (AI methods) is closely connected to cluster 2 (wargaming), confirming the convergence of AI and wargaming at the research front. This convergence already has practical manifestations: the GenWar Lab (JHU APL, 2025) integrates large language models (LLMs) with high-fidelity simulation platforms; Spahr, Mandle, and Stinchfield [14] described an experiment with LLM-adjudication in free Kriegsspiel at the U.S. Army War College. Saastamoinen and Rissanen [15] presented the Finnish edge AI model for tactical simulators – an architecture relevant to the Ukrainian Armed Forces under conditions of limited connectivity.

The temporal map of the target dataset (Fig. 4) refines the chronology.

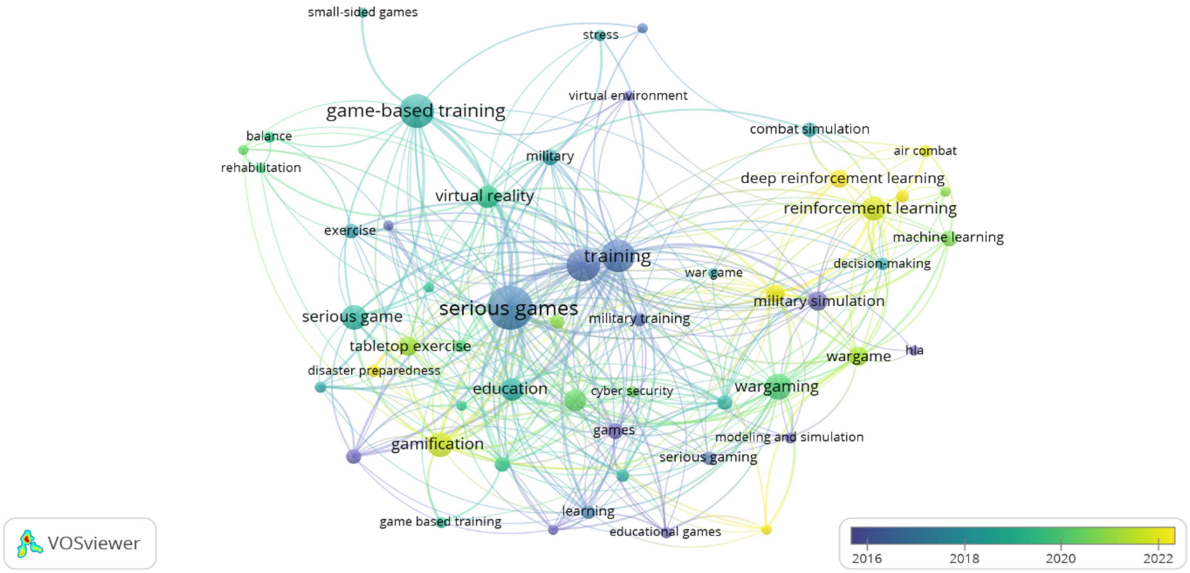

Fig. 4. Temporal co-occurrence map of the target dataset. VOSviewer, overlay visualization (scale 2016–2022).

The teal cluster (virtual reality, game-based learning) corresponds to subcategory UA-1227 «Modelling and Simulation» of the NATO C3 Taxonomy (ETEE) [16] – one of four official subcategories showing a «critical» gap in the higher military educational institutions (HMEIs), according to the content analysis conducted by the authors.

The oldest nodes (~2016–2017) – training, serious games – are established concepts that took shape before the wargaming renaissance. The middle zone (~2018–2019) – wargaming, military simulation – their activation correlates with the publication of the UK MoD Wargaming Handbook [17] and the growth of NATO institutional attention. The most recent (~2020–2022) – deep reinforcement learning, machine learning, cyber security – register a shift toward AI-enhanced simulations.

The quantitative dynamics confirm the visual pattern: publication activity in the target dataset increased fivefold – from 25 publications per year (average for

2005 – 2019) to 126 per year (2020–2025), with a peak of 187 publications in 2024 (Table 2). In the contextual dataset, growth is more moderate (from 159 to 226), indicating that it is specifically the wargaming segment that serves as the driver, rather than the broader «gaming» field.

Table 2

Chronological dynamics of publication activity

Indicator	Contextual dataset (n=3,962)	Target dataset (n=1,954)
Annual average, 2005–2019	159	25
Annual average, 2020–2025	226	126
Growth	×1,4	×5,0
Peak	2024 (274)	2024 (187)

Source: compiled by the authors based on Scopus data

The growth correlates with three events of 2022–2023: the publication of the NATO Wargaming Handbook [1], Russia's full-scale invasion of Ukraine, and the emergence of generative AI. The cumulative effect of these events accounts for the exponential character of the dynamics.

3. Geography: the international co-authorship network.

The co-authorship map by country (Fig. 5) reveals a concentration of research in NATO member states and their strategic partners.

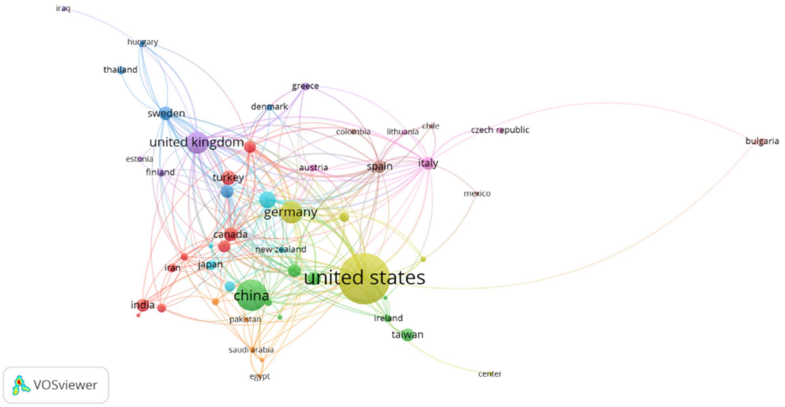

Fig. 5. Country-level co-authorship map, target Scopus dataset (n=1,954) VOSviewer, threshold – 3 documents. Ukraine is absent.

The United States dominates as the largest node by publication count and strength of international ties, with concentration at the Naval War College, RAND, CGSC, and JHU APL. China is the second largest, reflecting substantial investment in military modelling. Among European states, the United Kingdom (King's College London, Cranfield, DCDC), Germany, Sweden, and Finland stand out – all with well-established wargaming traditions in PME.

The temporal version adds a chronological dimension: the United States and the United Kingdom are the oldest participants (~2016–2017), while Lithuania, Estonia, and Türkiye joined more recently (~2020–2022). The appearance of the Baltic states signals growing research interest among NATO members that face a direct security threat. Finland, which shares a comparable security context (border with Russia,

NATO accession in 2023), is present on the map owing to the systematic integration of simulations into Defence Forces training [15].

Ukraine is absent from the map – no Ukrainian affiliation reached the entry threshold (3 documents). This academic isolation is not coincidental: according to the content analysis conducted by the authors, the PME system does not employ wargaming, and consequently generates neither practice nor research. The longer the system remains outside the research process, the wider not only the institutional but also the intellectual gap becomes: the NATO PME community is shaping new concepts, standards, and practices in whose development Ukraine takes no part.

4. Implications for Ukraine's PME system.

The bibliometric analysis reveals five structural characteristics of the research field, each carrying implications for the PME system.

Wargaming is an autonomous domain, not a subset of serious games. After filtering, wargaming forms a separate cluster with military simulation, spatially distinct from serious games (Fig. 3). For the PME system, this means that introducing serious games (gamification, game-based learning) does not substitute for introducing wargaming – these are different instruments with different pedagogical architectures, different facilitators, and different learning outcomes. The NATO Wargaming Handbook [1] identifies three constitutive elements of wargaming (player decisions, friction, adjudication) that are absent from typical serious games.

The convergence of AI and wargaming creates a leapfrogging window. The close connection between clusters 2 and 3 (Fig. 3) and the shift of the most recent nodes toward AI methods (Fig. 4) indicate that AI-enhanced wargaming is not a forecast but a current research front. For HMEIs where wargaming has not yet been operationalized (according to the authors' content analysis), this opens the possibility of anticipatory adoption. Wargaming can be integrated with AI support from the outset, bypassing the stage of costly legacy systems. The Finnish edge AI model wargaming with AI support from the outset, bypassing the stage of costly legacy systems. The Finnish edge AI model [15] demonstrates the technical feasibility of autonomous AI support even under conditions of limited connectivity – conditions directly relevant to the Ukrainian Armed Forces.

The Baltic states demonstrate the speed of entry. The appearance of Lithuania and Estonia on the co-authorship map (~2020–2022, Fig. 5) shows that a small state is capable of entering the wargaming research space within a few years. Toci [19] described the experience of the Baltic Defence College, where wargaming is conducted for officers from all three Baltic states. For Ukraine, which has a considerably larger PME system and unprecedented combat experience, absence from the map is not an objective constraint but a consequence of an institutional vacuum.

The combat experience of the Ukrainian Armed Forces is an untapped resource. The node «Ukraine» is present in the geopolitical cluster of the contextual dataset (Fig. 1), but as an object of other countries' research rather than as a subject. The international community – the U.S. Marine Corps University, RAND, WIN conferences – draws on Ukrainian combat experience for wargaming scenarios more actively than Ukraine's own PME system does. Transforming this experience into wargaming scenarios is not merely an educational task: structured scenarios of

contemporary combat are of value to the NATO PME community and can serve as the basis for joint publications – a mechanism for entering the Scopus map.

Three recommendations. Based on the identified structural characteristics, three recommendations for the PME system are formulated. First, include wargaming in PME course catalogues by order of the Ministry of Defence of Ukraine, specifying methodology, facilitator qualification requirements, and the requirement for structured debriefing. Without regulatory codification, wargaming will remain an initiative of individual instructors – a risk identified by RAND Europe [6] as the principal threat to the sustainability of wargaming programmes. Second, prepare a cohort of 10–15 wargaming facilitators through the DEEP programme or NSO courses, with subsequent scaling via a train-the-trainer model. A three-level integration framework (tabletop wargaming → CAX → AI-assisted) is described in detail by the authors in a separate study. Third, launch joint research projects with wargaming centres in NATO member states (King's College London Wargaming Network, NATO M&S Centre of Excellence) and publish in specialized journals (Journal of Defense Modeling and Simulation, Scandinavian Journal of Military Studies) – this constitutes the sole mechanism for Ukraine's entry onto the international co-authorship map (Fig. 5).

Conclusions. A bibliometric analysis of two Scopus datasets (contextual n=3,962, target n=1,954) with VOSviewer visualization revealed five structural characteristics of the global wargaming research field in military education. Mathematical game theory dominates the broad dataset quantitatively (233 occurrences versus wargaming – 27), necessitating two-stage filtering for a correct analysis of the wargaming discourse. After filtering, wargaming forms an autonomous cluster with military simulation (123 occurrences combined), spatially separated from serious games – confirming its status as a distinct PME instrument that requires its own implementation strategy. The convergence of AI methods and wargaming at the research front (Figs. 3–4) corresponds to practical developments at NATO PME institutions (GenWar Lab, CGSC Vantage, the Finnish edge AI model) and creates a leapfrogging window for states starting from scratch. Publication activity increased fivefold after 2020 (from 25 to 126 publications per year), signalling the transition of wargaming from a niche practice to the mainstream of NATO PME. Ukraine is absent from the international co-authorship map (Fig. 5) – no Ukrainian affiliation reached the threshold of 3 documents. This academic isolation corresponds with an institutional one: wargaming terminology is present in 8 of 79 regulatory acts (10 %) but operationalized in none; PME course catalogues (over 13,000 entries) contain no course with a wargaming component. Bridging the gap requires simultaneous action in three directions: regulatory codification of wargaming in course catalogues, facilitator training through NATO programmes, and joint research projects as the mechanism for entering the Scopus map.

The scientific novelty of this study lies in two contributions. It is the first bibliometric analysis of wargaming in the PME context that employs two-stage filtering to separate wargaming discourse from the broader «military games» field dominated by mathematical game theory. It also provides the first empirical evidence of Ukraine’s absence from the international wargaming research network,

corroborated by a parallel content analysis of national regulatory acts.

Several limitations should be noted. The analysis relies on a single database (Scopus); departmental publications and restricted military reports, which may contain relevant wargaming research, are not captured. The co-occurrence method maps the field through author-assigned keywords, which may not fully reflect the substantive content of publications. The co-authorship map measures formal collaboration at the publication level and does not account for informal knowledge exchange through conferences, exercises, or bilateral programmes.

Directions for further research. Extending the bibliometric analysis to include Web of Science and restricted military publications would allow verification of the identified structural characteristics. Pilot implementation of wargaming at two HMEIs of different profiles would provide an empirical basis for assessing the learning effect in the Ukrainian context. Research into the effectiveness of LLM-adjudication in the free Kriegsspiel format under wartime information security constraints would determine the feasibility of transitioning to AI-assisted wargaming.

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