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A bibliometric analysis of agentic AI and the agentic pedagogical agency framework

Serap Ugur

Faculty of Education, Anadolu University, Türkiye.
Email: serapsisman@anadolu.edu.tr

Abstract

The rapid evolution of generative artificial intelligence (GenAI) has given rise to agentic artificial intelligence (AI) systems capable of autonomous planning, reasoning, and goal-oriented action, positioning education at the center of a profound pedagogical transformation. Despite growing interest, research on agentic (AI) in education remains conceptually fragmented and unevenly theorized. This study aims to systematically map the intellectual, conceptual, and collaborative structures of the Agentic AI and Education literature and to advance a pedagogically grounded framework for understanding agency in AI-mediated learning environments. Using a comparative bibliometric research design, publications indexed in the Web of Science Core Collection (WoS) and Scopus were analyzed through keyword co-occurrence, co-citation, bibliographic coupling, and co-authorship networks visualized with VOSviewer. The findings reveal a clear epistemic divergence between databases: while WoS emphasizes technological legitimacy, ethics, and governance, Scopus foregrounds applied pedagogical contexts, learner autonomy, and human–AI collaboration. Across both datasets, agentic AI is predominantly framed through technological constructs, with pedagogical agency remaining underarticulated. To address this gap, the study proposes the Agentic Pedagogical Agency Framework (APAF), conceptualizing agency as a relational and dynamic construct distributed among learners, teachers, agentic AI systems, and educational institutions across shared, delegated, and negotiated modes. By integrating bibliometric evidence with theoretical synthesis, this study contributes a novel analytical lens for interpreting agentic AI in education and offers directions for research, practice, and governance in emerging AI-mediated learning ecosystems. Rather than reviewing all educational applications of agentic AI, this study centers on agency as the core analytical construct shaping AI-mediated education.

Keywords:
Agentic AI
AI agent
Education
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1. Introduction

As of 2025, educational technology has entered a profound paradigm shift that industry leaders increasingly describe as the "Year of AI Agents," marking a transition from reactive generative systems to goal-driven, autonomous, and adaptive artificial intelligence(AI) architectures (Adabara, Sadiq, Shuaibu, Danjuma, & Maninti, 2025; Borghoff, Bottoni, & Pareschi, 2025). While early generative AI (GenAI) applications in education were largely limited to command-based content generation and surface-level interaction, recent developments have enabled AI systems to autonomously plan tasks, reason across multiple steps, interact with external tools, and execute outcome-oriented actions. These emerging systems—commonly referred to as agentic artificial intelligence (AgAI)—represent not merely a technical evolution but a fundamental pedagogical rupture that challenges existing assumptions about learner autonomy, instructional design, and institutional governance (Abou Ali, Dornaika, & Charafeddine, 2025; Kremantzis, Essien, Pantano, & Lythreatis, 2025).

Forecasts indicate that by 2028, approximately one-third of enterprise software systems will incorporate agentic capabilities, positioning higher education institutions at a critical crossroads where the speed and depth of AgAI integration may directly shape educational equity, access, and learning outcomes (Kamalov et al., 2025; Sargsyan, 2025). In this context, education is no longer a passive recipient of technological innovation but an active site where agency—traditionally attributed to learners and educators—is redistributed, negotiated, and partially delegated to intelligent systems. Consequently, understanding agentic AI within educational ecosystems necessitates a shift from tool-oriented adoption narratives toward a theoretically grounded examination of agency, responsibility, and pedagogical transformation.

1.1. Conceptual and Technical Foundations of the Agentic Paradigm

Agentic artificial intelligence is broadly defined as a class of systems capable of acting independently to achieve user-defined or self-generated goals through high levels of autonomy, planning, reasoning, memory persistence, tool use, and contextual awareness (Acharya, Kuppan, & Divya, 2025; Kostopoulos, Gkamas, Rigou, & Kotsiantis, 2025). The literature suggests that for an AI system to be classified as agentic, it must satisfy at least four of six core criteria: autonomy, multi-step reasoning and planning, persistent memory, goal-oriented interaction, adaptive tool use, and contextual sensitivity (Kostopoulos et al., 2025). Unlike conventional conversational agents that operate within isolated interaction sessions, agentic systems maintain long-term contextual continuity, enabling them to function as digital companions, instructional assistants, or collaborative learners capable of supporting sustained educational trajectories (Kremantzis et al., 2025).

Technically, agentic architectures reposition large language models (LLMs) as cognitive processing units embedded within broader decision-making frameworks rather than standalone generators of text (Shah et al., 2025). Through continuous feedback loops, planning modules, and execution layers, agentic systems dynamically adjust their actions based on learner behavior, progress, and contextual constraints. In educational settings, this architectural shift enables AI systems to move beyond static FAQ bots toward personalized, longitudinal learning support mechanisms that adapt over an academic term, rather than within isolated interactions (Kostopoulos et al., 2025).

A particularly significant development within this paradigm is the emergence of agentic retrieval-augmented generation (Agentic RAG). Traditional RAG systems, constrained by predefined retrieval pipelines, often struggle with complex, multi-step educational queries. Agentic RAG architectures introduce a reasoning layer that enables the system to determine when, how, and from which sources information should be retrieved, summarized, or transformed (Kukreja, Morande, & Tewari, 2025; Panguraj, 2025; Taneja, Biswas, Alankar, & Kaur, 2025). Experimental implementations such as KA-RAG demonstrate substantial improvements in access accuracy and semantic coherence in postgraduate learning contexts, underscoring the pedagogical potential of agentic reasoning in higher education (Gao, Xu, Hao, & Lu, 2025).

1.2. Agency, Motivation, and Socio-Materiality in Agentic Learning Environments

The integration of agentic AI into educational contexts necessitates a reconceptualization of agency at both individual and systemic levels. Self-Determination Theory (SDT) provides a foundational framework for understanding how agentic interactions influence learner motivation through autonomy, competence, and relatedness (Kremantzis et al., 2025). Agentic AI systems can support learner autonomy by offering meaningful choices, enhance competence through timely and adaptive feedback, and foster relatedness via socially responsive interaction patterns (Li & Chiu, 2025; Wu, Yuan, & Deng, 2025). Empirical evidence suggests that AI-mediated learning environments may, under certain conditions, elicit levels of emotional engagement comparable to—or exceeding—those associated with human instructors, particularly by reducing performance anxiety and social pressure (Li & Chiu, 2025).

Beyond individual motivation, agentic AI functions as a form of proxy agency, extending learners' and educators' capacities to act within complex educational systems (Kremantzis et al., 2025). This extension foregrounds the concept of augmented socio-materiality, wherein digital artifacts acquire agentic properties traditionally reserved for human actors (Johri, Dwivedi, & Pal, 2025). By assuming roles in decision-making, feedback provision, and learning orchestration, agentic systems transform representational and relational

dynamics within educational environments, blurring the boundaries between human and non-human agency (Costa, Bryda, Christou, & Kasperiuniene, 2025).

Complementary theoretical perspectives further emphasize the non-neutrality of AI-mediated learning. The concept of subjective intelligence highlights how learners' cultural, linguistic, and academic identities shape—and are shaped by—agentic interactions (Bandi, Kongari, Naguru, Pasnoor, & Vilipala, 2025). Similarly, Proactive Language Learning Theory (PLLT) conceptualizes language acquisition as an agentic process in which learners actively engage with linguistic resources embedded in their environments, a process increasingly mediated by AI agents capable of adaptive scaffolding (Papi & Hiver, 2025).

1.3. Disciplinary Applications and Pedagogical Transformation

Across disciplines, agentic AI has begun to reshape pedagogical practices by reallocating cognitive effort and enabling higher-order learning. In STEM education, agentic feedback loops reduce extraneous cognitive load, allowing learners to focus on complex problem-solving and conceptual integration (Pop, Ţonţ, Flonta, & Flore, 2025). In programming education, agentic systems facilitate a transition from code production to system-level architectural thinking, positioning learners as designers rather than mere implementers (Wu et al., 2025).

In business education, agentic AI supports simulation-based learning environments in which multi-agent systems dynamically respond to student decisions, enabling iterative testing of strategic reasoning in complex market scenarios (Huo & Siau, 2025; Kremantzis et al., 2025). Similarly, in health sciences education, agentic workflows accelerate simulation design processes and support autonomous decision-making in surgical planning and patient education, significantly enhancing instructional efficiency and realism (Barra et al., 2025; Oettl et al., 2025).

1.4. Institutional Transformation and Governance: Toward the Agentic University

At the institutional level, the adoption of agentic AI signals a shift toward what has been termed the "Agentic University," wherein AI systems function as integrated components of digital infrastructure rather than isolated educational tools (Ashwani, 2025; Schroeder, 2025). In this model, agentic systems support student advising, academic libraries, and administrative operations through autonomous decision-making and workflow optimization (Sakthivel, 2025; Wang & Chou, 2025). However, this transformation raises critical governance challenges related to accountability, leadership, and ethical oversight.

Recent studies indicate a strong preference among stakeholders for human-in-the-loop governance models, reflecting concerns about transparency, trust, and institutional responsibility in fully autonomous systems (Bowen, 2025; Henderson, 2025). Concurrently, global regulatory frameworks—including the European Union's AI Act and guidelines from UNESCO and the OECD—classify educational AI systems as high-risk applications, mandating algorithmic transparency, human oversight, and ethical safeguards (Khan, Joyce, & Habiba, 2025).

1.5. Research Need and Rationale

Despite rapid technological advancement, the literature on agentic AI in education remains conceptually fragmented and unevenly theorized. Bibliometric evidence from WoS and Scopus reveals a pronounced epistemic divergence: while WoS emphasizes technology-driven and theoretically anchored AI research, Scopus increasingly foregrounds pedagogical, ethical, and applied dimensions of agentic systems. This divergence underscores a critical gap in which education has yet to articulate a cohesive agentic framework that integrates learner, teacher, AI, and institutional agency within a unified pedagogical model.

1.6. Purpose of the Study and Research Questions

The purpose of this study is to systematically map and compare the intellectual, conceptual, and collaborative structures of the Agentic AI and Education literature using bibliometric data from WoS and Scopus. By synthesizing these findings, the study aims to identify emerging trends, conceptual gaps, and future research directions that can inform the development of a pedagogically grounded agentic framework for education.

Accordingly, the study addresses the following research questions:

- What thematic structures characterize the Agentic AI and Education literature in WoS and Scopus, and how do these structures differ across databases?
- Which authors, references, and theoretical traditions constitute the intellectual foundations of the field?
- What emerging research trajectories can be identified through citation and bibliographic coupling analyses?
- How do patterns of international, institutional, and author-level collaboration shape the development of the field?
- What conceptual gaps do current bibliometric patterns reveal regarding the redistribution of agency among learners, educators, AI systems, and institutions?

2. Methodology

2.1. Research Design

This study adopts a comparative bibliometric research design to systematically map and analyze the intellectual, conceptual, and collaborative structures of the Agentic Artificial Intelligence and Education literature. Bibliometric analysis was selected as the primary methodological approach due to its capacity to reveal large-scale knowledge structures, thematic evolution, and epistemic patterns across disciplines and databases (Van Eck & Waltman, 2014). In contrast to narrative or systematic reviews that rely on selective interpretation, bibliometric methods enable an objective, data-driven examination of scholarly communication through citation relationships, keyword co-occurrence, and collaboration networks.

Given the emerging and interdisciplinary nature of agentic AI in education, a dual-database strategy was employed by integrating data from WoS and Scopus. This approach allows for a comparative analysis of how different indexing logics—WoS's emphasis on theoretical consolidation and Scopus's broader coverage of applied and interdisciplinary research—shape the representation of agentic AI within educational contexts. Threshold values were selected to balance network interpretability and analytical robustness, following established practices in educational bibliometric research

3. Data Sources and Search Strategy

3.1. Scopus Data Collection

Scopus was selected to capture the applied, pedagogical, and interdisciplinary dimensions of agentic AI research in education. Two complementary search queries were executed to ensure comprehensive coverage of terminological variations within the field.

(TITLE-ABS-KEY (ai agent) AND ALL (education)) AND (LIMIT-TO (SUBJAREA, "SOCI")).

The inclusion of both "agentic AI" and "AI agent" ensured sensitivity to evolving terminology, while the subject area restriction to Social Sciences (SOCI) in the first query was applied to foreground educational, sociological, and pedagogical perspectives. No temporal restrictions were imposed in order to capture the full historical emergence and acceleration of agentic AI discourse within education. Only peer-reviewed journal articles and conference papers indexed in Scopus were included.

3.2. Web of Science Data Collection

The WoS Core Collection was utilized to identify theoretically grounded and high-impact research shaping the intellectual foundations of agentic AI in education. Two relevance-ranked WoS searches were conducted using advanced query formulations accessible through the platform's interface.

Search Query:

https://www.webofscience.com/wos/woscc/summary/7aef2d05-4115-40ed-8b4d-b644fee603bb-019789e21d/date-ascending/1

These searches targeted records containing agentic AI, AI agents, and closely related constructs within educational contexts. Consistent with best practices in bibliometric research, only documents indexed in the Social Sciences Citation Index (SSCI) and Emerging Sources Citation Index (ESCI) were retained to ensure academic rigor and relevance.

3.3. Inclusion and Exclusion Criteria

To enhance methodological transparency, the following criteria were applied consistently across both databases.

Inclusion criteria

- Peer-reviewed journal articles and conference proceedings.
- Publications explicitly addressing agentic AI, AI agents, or autonomous intelligent systems in educational contexts.
- Documents indexed in WoS Core Collection or Scopus.
- English-language publications.

Exclusion criteria

- Editorials, book reviews, notes, and non-scholarly documents.
- Studies focusing exclusively on technical AI architectures without educational relevance.
- Duplicated records across databases.

After initial retrieval, all records were exported in BibTeX format and screened for relevance through title and abstract inspection prior to analysis. To contextualize the scope and composition of the datasets analyzed in this study, the descriptive characteristics of the WoS and Scopus records are summarized in Table 1. This overview provides a baseline for interpreting subsequent bibliometric patterns across databases.

Table 1. Descriptive characteristics of the agentic AI and education literature.

Database	Number of Publications	Dominant Document Types	Time Span	Primary Focus
Web of Science	827	Journal articles	1997–2025	Theoretical, ethical, governance-oriented
Scopus	1134	Journal articles & conference papers	1998–2025	Applied, pedagogical, interdisciplinary

This table summarizes the basic descriptive characteristics of the datasets used in the study. The contrast highlights WoS emphasis on theoretical consolidation and Scopus's broader coverage of applied and pedagogical research.

4. Data Analysis Procedures

Bibliometric analyses were conducted using VOSviewer (Version 1.6.x), a widely adopted tool for constructing and visualizing bibliometric networks (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021). Separate analyses were performed for WoS and Scopus datasets to preserve database-specific epistemic structures prior to comparative synthesis.

The following analyses were carried out.

- Keyword co-occurrence analysis to identify dominant and emerging conceptual themes.
- Co-citation analysis (Authors and references) to reveal the intellectual foundations and theoretical lineages of the field.
- Bibliographic coupling and citation network analysis to detect contemporary research trajectories and thematic convergence.
- Co-authorship analysis at author, institutional, and country levels to examine collaboration patterns and global knowledge production.

Threshold values for inclusion (e.g., minimum number of occurrences or citations) were determined iteratively to balance network readability with analytical depth, following established bibliometric conventions. Visualization layouts were generated using the association strength normalization method to ensure comparability across networks.

4.1. Comparative Analytical Framework

Following database-specific analyses, findings from WoS and Scopus were systematically compared to identify convergences and divergences in thematic focus, theoretical orientation, and collaboration structures. This comparative framework enabled the identification of epistemic tensions between technology-centered and pedagogy-centered interpretations of agentic AI in education. Particular attention was paid to how concepts such as agency, autonomy, trust, ethics, and human–AI collaboration were positioned within each database's knowledge structure.

4.2. Methodological Rigor and Limitations

To enhance reliability, all analytical procedures were documented in detail to ensure replicability. Nevertheless, certain limitations should be acknowledged. Bibliometric analyses are inherently dependent on database indexing practices and may underrepresent emerging work not yet indexed. Additionally, the use of English-language publications may exclude relevant research published in other languages. Despite these limitations, the combined use of WoS and Scopus provides a robust and balanced representation of the field's current state.

5. Findings

5.1. Conceptual Structure of Agentic AI Research in Education

The keyword co-occurrence analysis based on the WoS dataset reveals a conceptually centralized yet pedagogically peripheral structure of agentic AI research in education, see Figure 1. In this network, *artificial intelligence*, *large language models*, and *chatbots* occupy the most central positions, while educational constructs such as *learner autonomy*, *instructional design*, and *teacher education* appear in smaller, loosely connected clusters. This configuration suggests that, within WoS-indexed scholarship, agentic AI is predominantly framed as a technological phenomenon, with pedagogical considerations emerging as secondary or downstream concerns.

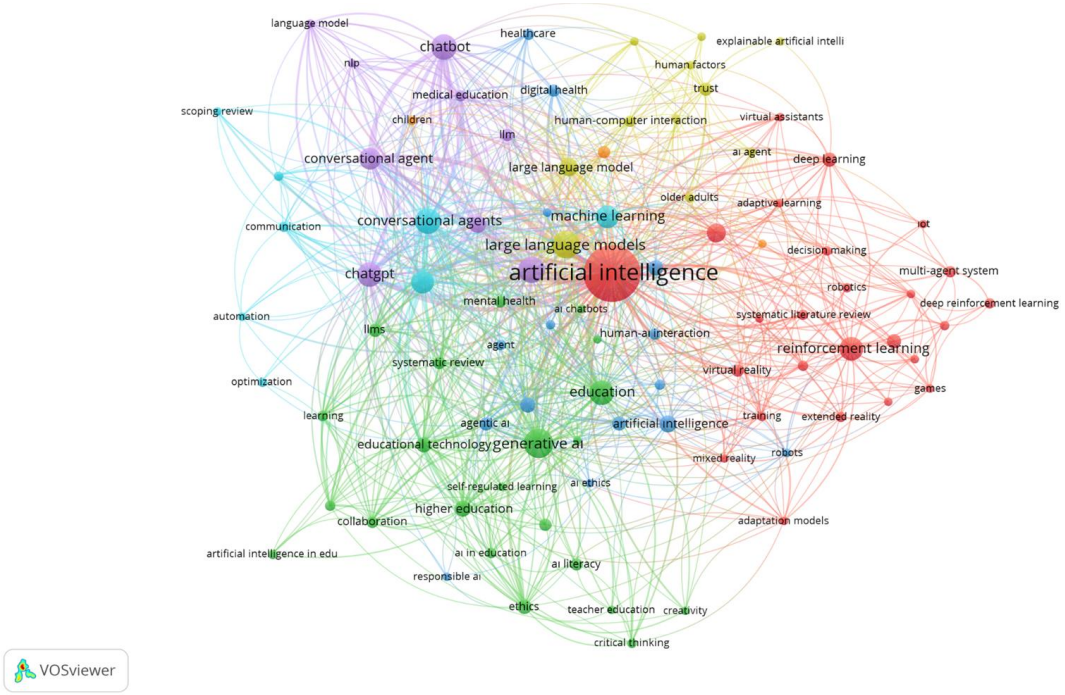

Figure 1. Keyword co-occurrence network (WoS dataset).

By contrast, the Scopus keyword co-occurrence network demonstrates a more integrated conceptual configuration between agentic AI and educational constructs, see Figure 2.

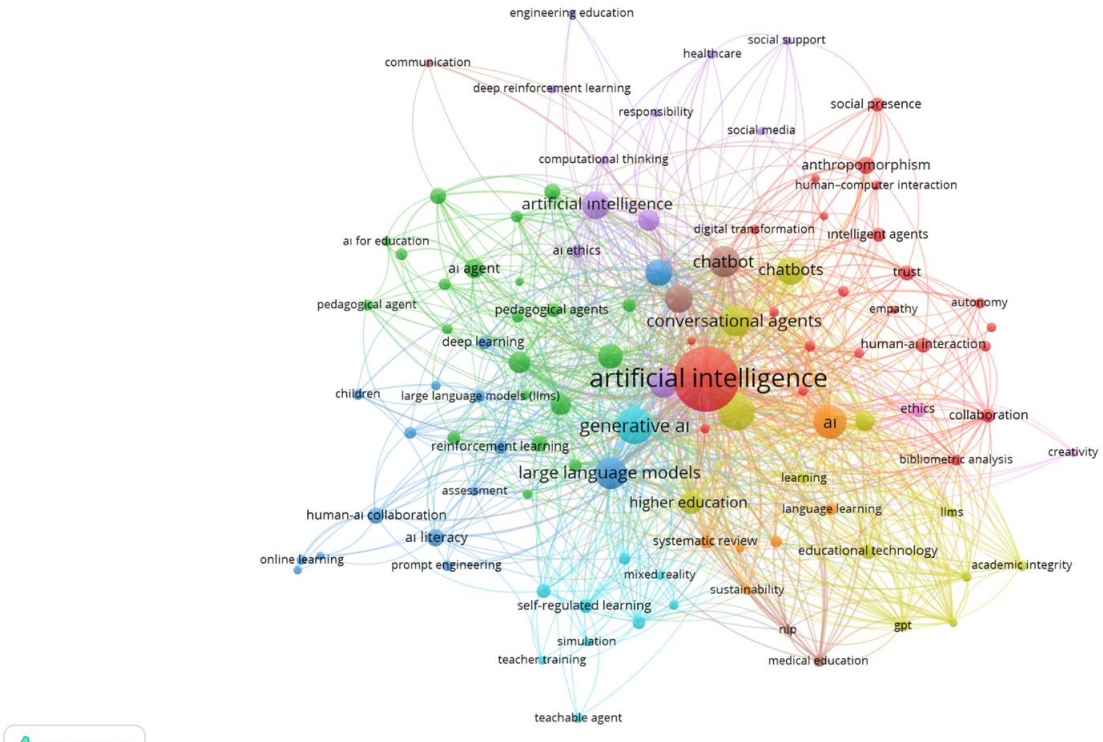

Figure 2. Keyword co-occurrence network (Scopus dataset).

Terms such as self-regulated learning, AI literacy, human–AI collaboration, and higher education are positioned closer to the technological core, indicating that Scopus-indexed studies increasingly conceptualize agentic AI as an active pedagogical participant rather than a background computational infrastructure. This divergence between datasets highlights an epistemic distinction: while WoS prioritizes conceptual consolidation and technological legitimacy, Scopus reflects practice-oriented experimentation and instructional application. This suggests that Scopus-indexed literature places greater emphasis on applied educational contexts and

learner-centered outcomes, aligning with recent calls to reposition AI systems as co-regulators rather than mere content generators (Li & Chiu, 2025). In contrast, the WoS network exhibits a more pronounced separation between technological and pedagogical clusters, reflecting a field that is still negotiating the epistemic legitimacy of agentic AI within education.

While the keyword co-occurrence networks visualize the conceptual structure of the field, a synthesized overview of the major thematic clusters and their database-specific emphases is presented in Table 2 to facilitate systematic comparison and interpretation.

Table 2. Major keyword clusters identified through keyword co-occurrence analysis.

Cluster theme	Representative keywords	Database emphasis
Technological core	Artificial intelligence, LLMs, chatbots, reinforcement learnin	WoS & Scopus
Pedagogical processes	Self-regulated learning, instructional design, feedback	Scopus
Human–AI Interaction	Conversational agents, collaboration, trust	Scopus
Ethics & Governance	Ethics, accountability, transparency	WoS
Institutional applications	Higher education, policy, management	WoS & Scopus

Clusters were identified based on VOSviewer keyword co-occurrence networks. Database emphasis indicates where clusters appear more centrally and densely.

5.2. Intellectual Foundations and Knowledge Fragmentation

The co-citation network of cited authors in the WoS dataset further clarifies the intellectual foundations of agentic AI research in education (see Figure 3).

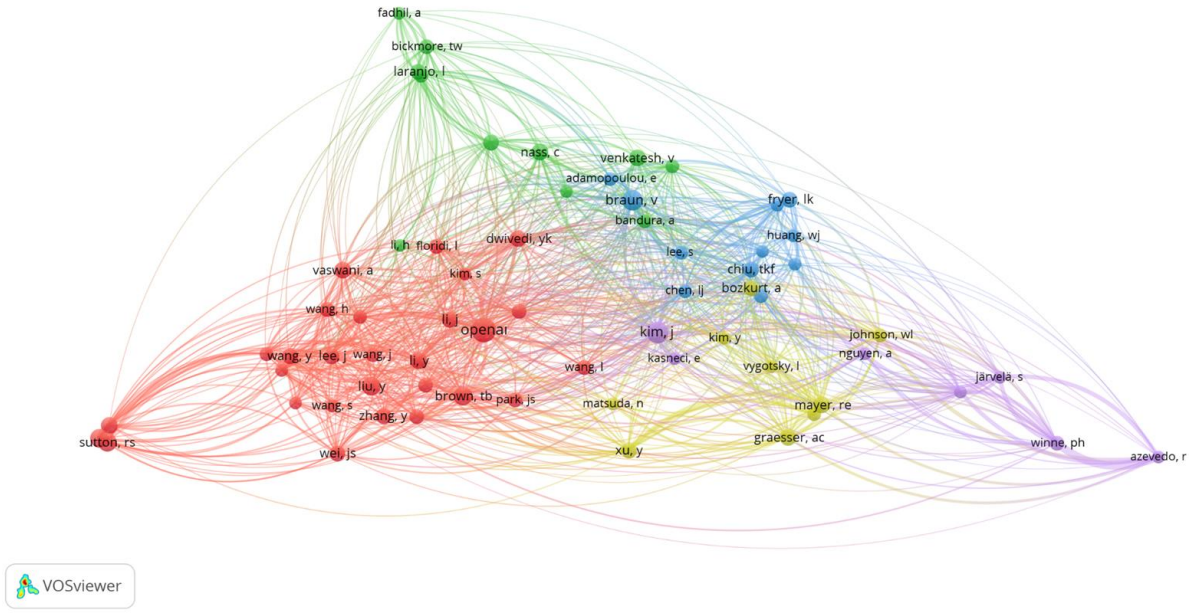

Figure 3. Co-citation network of cited authors (WoS dataset).

Highly cited works are predominantly drawn from artificial intelligence, human–computer interaction, and ethical AI literatures, with comparatively fewer canonical references from educational theory. This imbalance indicates that agentic AI in education remains theoretically anchored in adjacent disciplines rather than grounded in established pedagogical frameworks (Johri et al., 2025; Kremantzis et al., 2025).

A similar pattern is observed in the co-citation network of cited references (see Figure 4), where clusters related to ethics, trust, and governance form distinct but partially isolated knowledge bases.

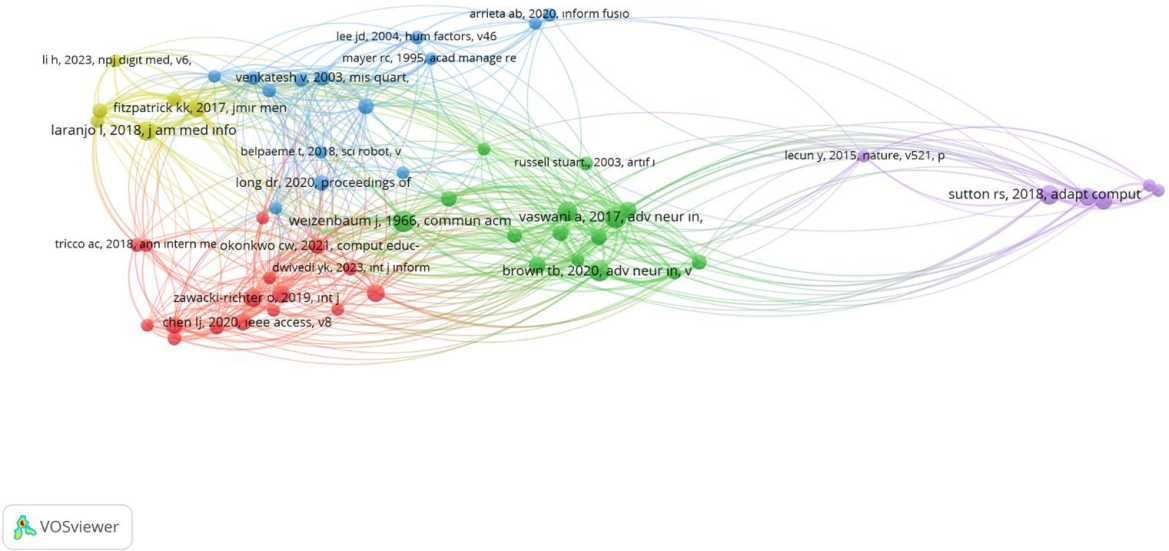

Figure 4. Co-citation network of cited references (WoS dataset).

Notably, ethical considerations—particularly those related to trust, accountability, and transparency—form a distinct yet partially isolated cluster in the WoS dataset. This pattern suggests that ethical discourse is developing in parallel with, rather than embedded within, pedagogical research. Such fragmentation risks creating a disconnect between normative principles and instructional practice, a concern echoed in recent governance-oriented studies emphasizing the need for human-in-the-loop and explainable agentic systems in educational settings (Henderson, 2025; Saeed & Prybutok, 2026).

To further clarify the intellectual foundations underpinning agentic AI research in education, the dominant knowledge bases identified through co-citation analysis are summarized in Table 3, highlighting the disciplinary origins shaping the field.

Table 3. Intellectual foundations of agentic AI in education based on Co-citation analysis.

Knowledge base	Dominant disciplines	Representative contributions
AI & HCI	Artificial intelligence, human–computer interaction	Autonomy, intelligent agents, interaction design
Ethics & Governance	Ethical AI, regulation	Trust, accountability, transparency
Learning Sciences	Educational psychology, learning sciences	Self-regulated learning, motivation
Socio-Technical Systems	Sociology of technology	Agency, socio-materiality

The co-citation structure demonstrates that agentic AI in education is grounded primarily in technological and ethical disciplines, with pedagogical theory occupying a secondary role.

5.3. Emerging Research Trajectories and Application Domains

Bibliographic coupling analysis provides insight into the field's emerging research trajectories by identifying groups of publications that share common reference bases (see Figure 5).

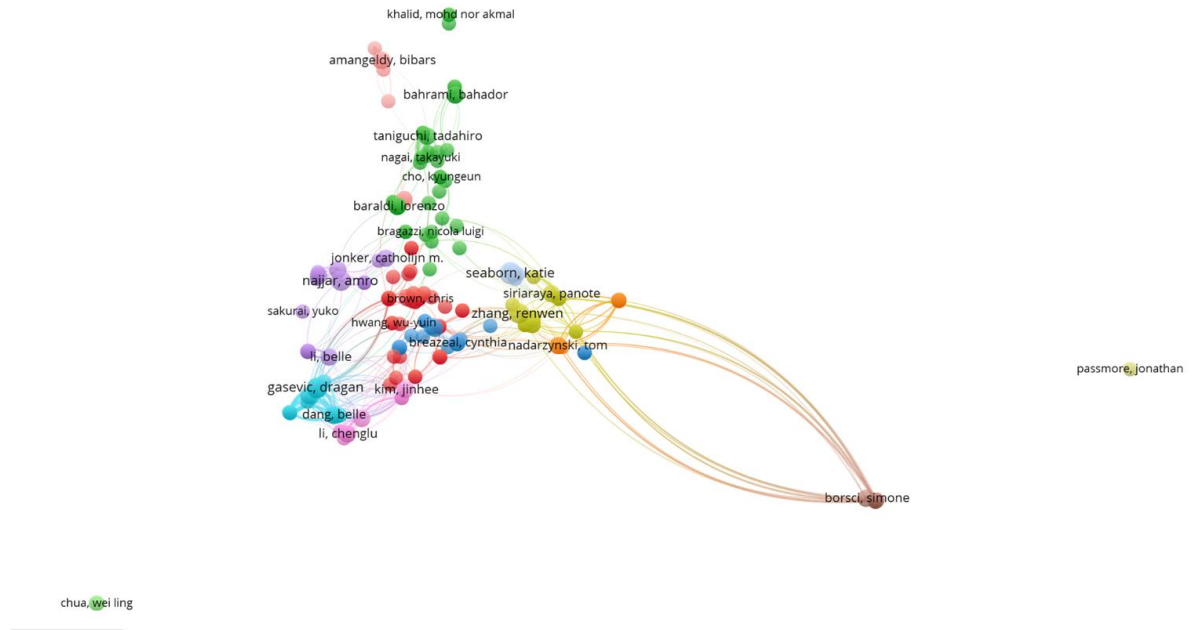

Figure 5. Bibliographic coupling network (WoS dataset).

Bibliographic coupling analyses reveal several emerging research trajectories that signal a shift toward more application-oriented and discipline-specific implementations of agentic AI. Clusters focusing on adaptive learning, reinforcement learning, and multi-agent systems indicate growing interest in systems capable of autonomous planning and context-sensitive decision-making. These trajectories are particularly evident in STEM education, business simulations, and healthcare training, where agentic systems support complex problem-solving and scenario-based learning (Huo & Siau, 2025; Pop et al., 2025).

Complementing this perspective, the citation network of documents highlights influential publications that act as bridges between technological innovation and educational application (see Figure 6).

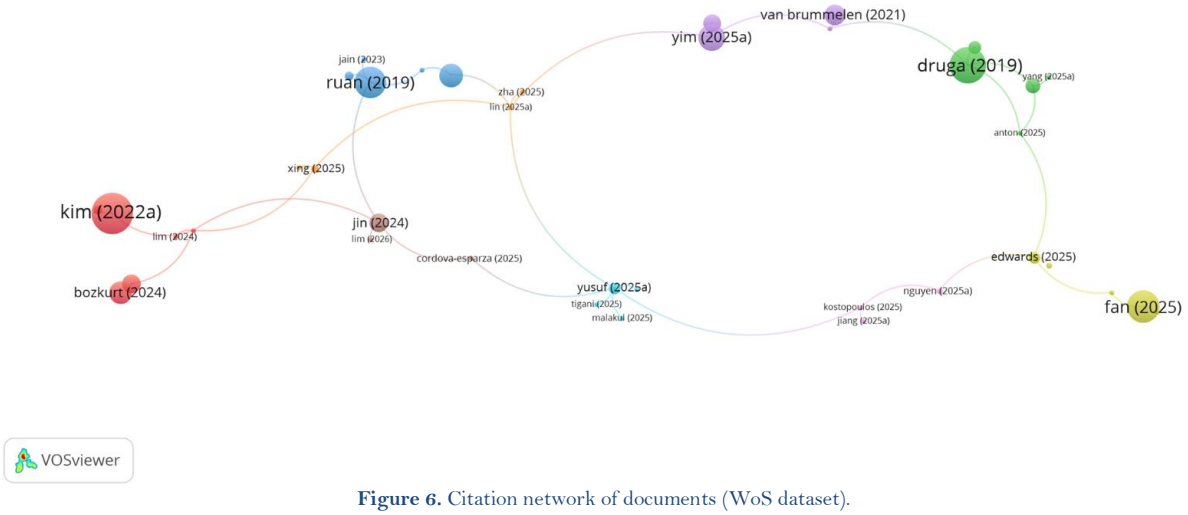

Figure 6. Citation network of documents (WoS dataset).

At the same time, the relatively sparse representation of K–12 education and teacher education contexts suggests that agentic AI adoption remains uneven across educational levels. This finding aligns with broader concerns regarding institutional readiness and the scalability of agentic systems in settings characterized by rigid curricula and high accountability pressures (Schroeder, 2025).

Beyond foundational influences, bibliographic coupling analysis reveals emerging research trajectories that signal the field's developmental direction. These trajectories, along with their primary educational contexts, are synthesized in Table 4.

Table 4. Emerging research trajectories identified via bibliographic coupling.

Trajectory	Core focus	Educational context
Adaptive Learning Systems	Personalized pathways, feedback automation	Higher education
Multi-Agent Architectures	Autonomous coordination, simulation	Business, STEM
Reinforcement-Based Learning	Decision optimization, planning	Programming education
Ethical AI in Education	Governance, human oversight	Institutional policy

Bibliographic coupling reveals emerging trajectories that reflect a shift from experimental adoption toward structured educational applications of agentic AI.

5.4. Collaboration Patterns and Global Knowledge Production

Country-level co-authorship analysis based on the WoS dataset reveals a globally distributed yet asymmetrical collaboration structure (see Figure 7).

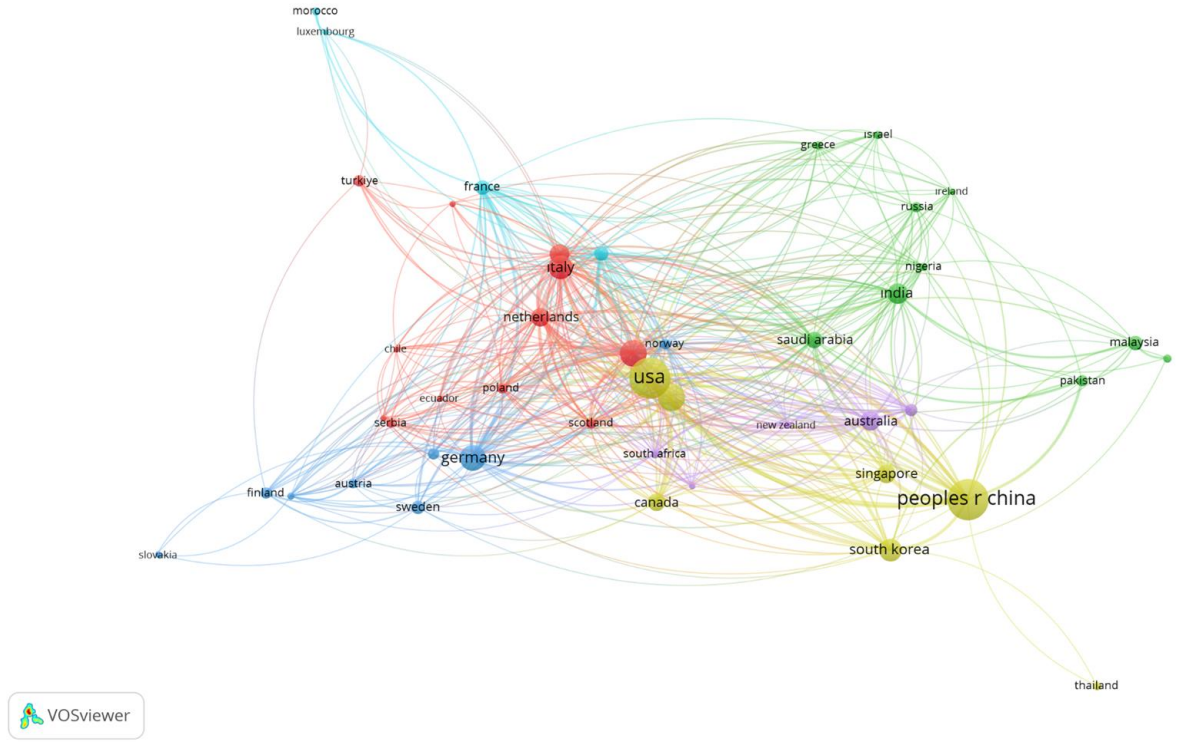

Figure 7. Co-authorship network by countries (WoS dataset).

The co-authorship analyses at the country, institutional, and author levels demonstrate that agentic AI research in education is globally distributed but unevenly coordinated. The United States and China occupy central positions in both WoS and Scopus networks, serving as primary hubs of knowledge production and international collaboration. European countries—particularly the United Kingdom, Italy, and the Netherlands—form secondary clusters that often bridge technological and social science perspectives.

At the institutional level, co-authorship networks indicate that agentic AI research in education is primarily driven by interdisciplinary collaborations involving artificial intelligence, engineering, and social science units rather than education faculties alone (see Figure 8). This interdisciplinary orientation fosters innovation but may also contribute to the marginalization of pedagogical theory within the field.

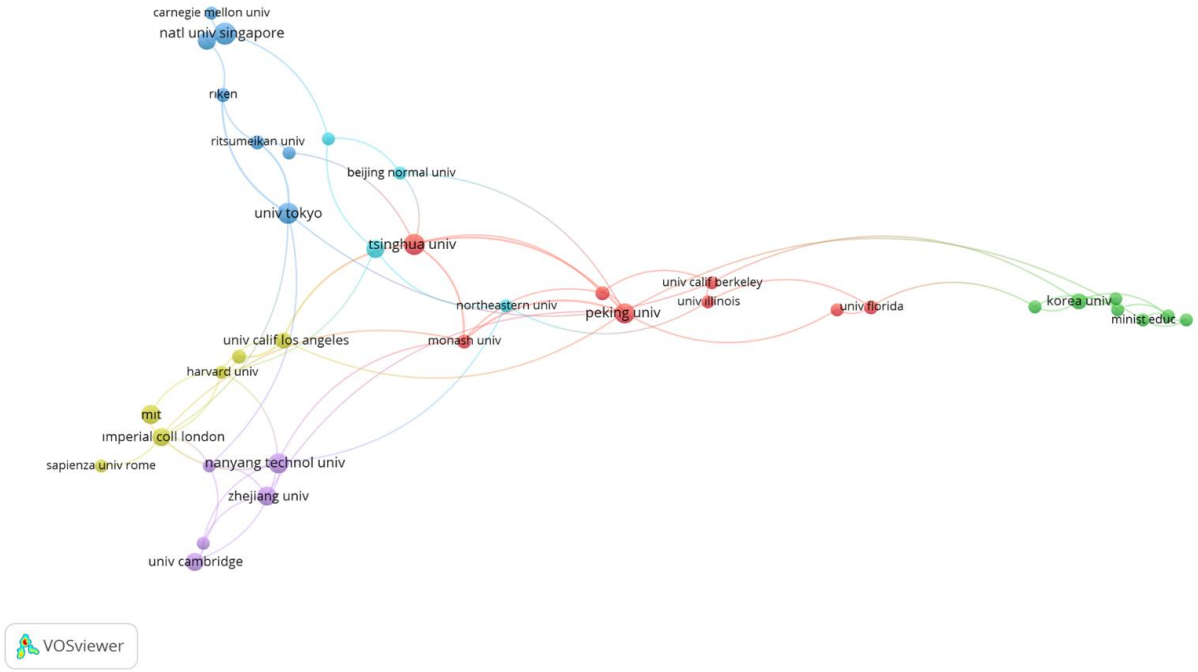

Figure 8. Co-authorship network by organizations (WoS dataset).

Author-level co-authorship patterns further illustrate the field's developmental stage (see Figure 9). The presence of small, tightly connected clusters suggests project-based collaboration rather than the emergence of established research schools. This fragmentation underscores the absence of canonical authors and reinforces the need for integrative, theory-building studies.

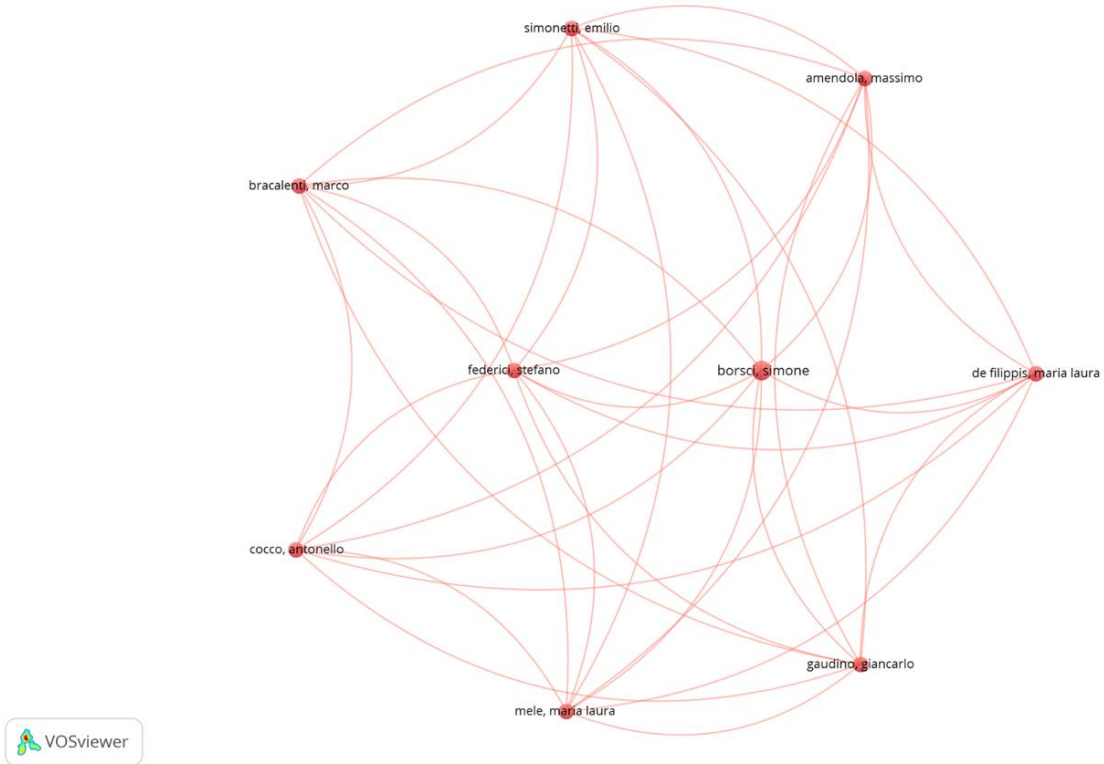

Figure 9. Co-authorship network by authors (WoS dataset).

Scopus-based collaboration networks reveal a broader and more inclusive global participation (see Figures 10–12). In particular, increased contributions from emerging and middle-income countries reflect the growing relevance of agentic AI for addressing scalability, access, and efficiency challenges in higher education. However, similar to WoS, author-level networks remain fragmented, indicating that conceptual consolidation has yet to occur across datasets.

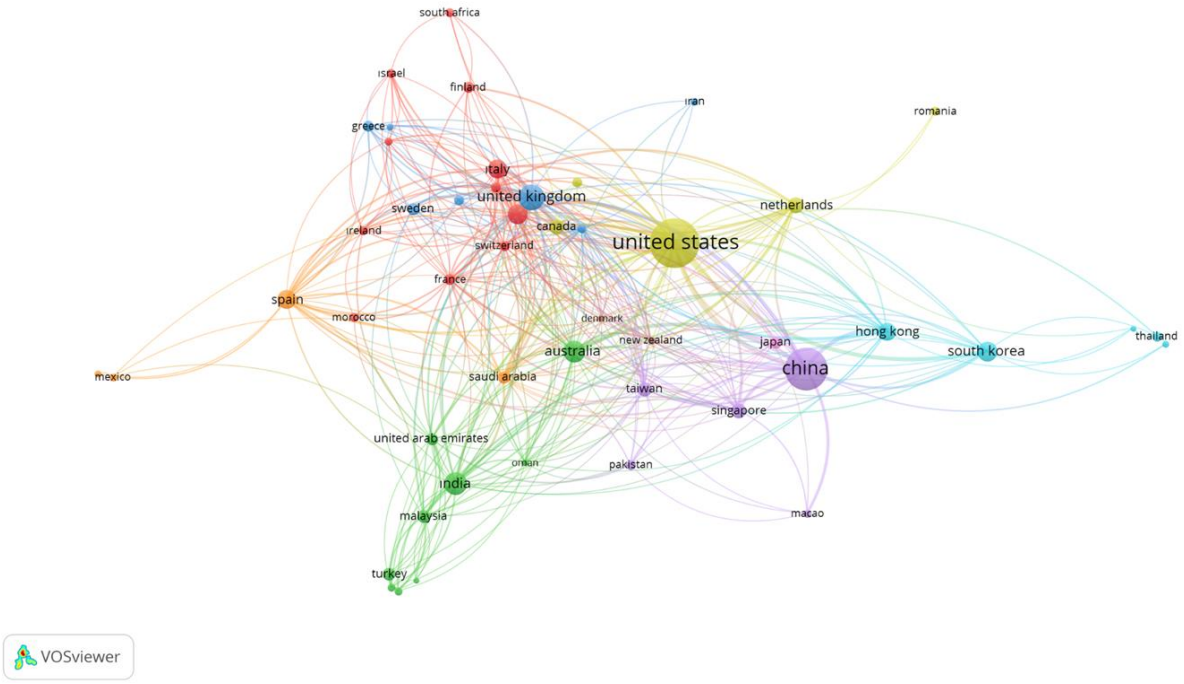

Figure 10. Co-authorship network by countries (Scopus dataset).

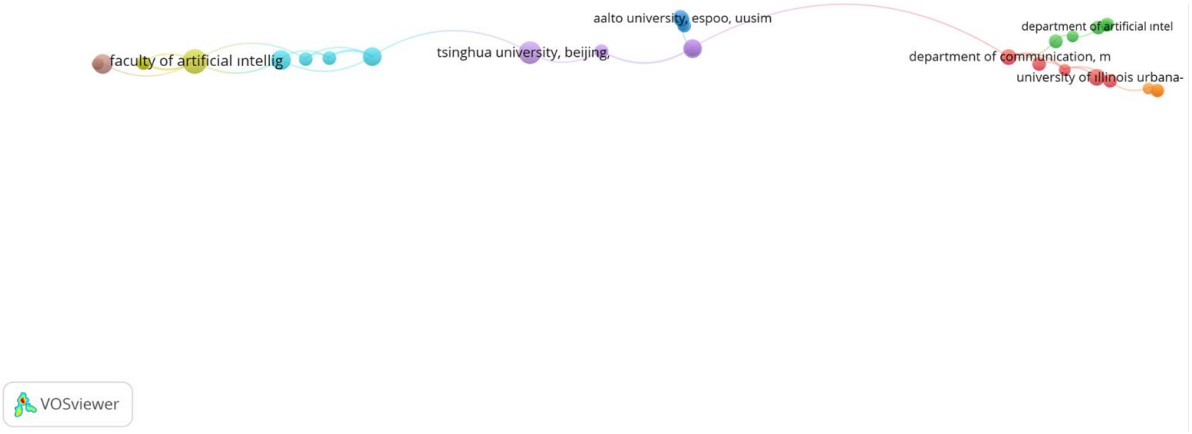

Figure 11. Co-authorship network by organizations (Scopus dataset).

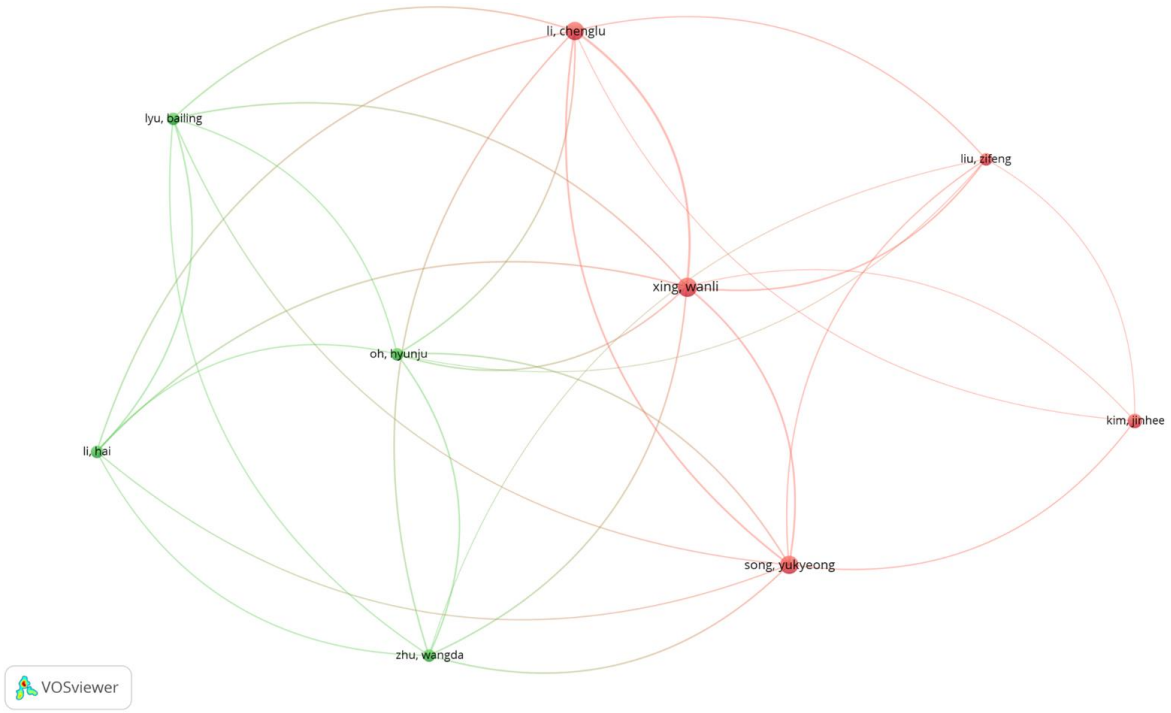

Figure 12. Co-authorship network by authors (Scopus dataset).

Scopus data further reveal increased participation from emerging and middle-income countries, including India, Türkiye, and Malaysia, particularly in applied and policy-oriented research. This trend reflects the growing global relevance of agentic AI for addressing scalability and access challenges in higher education (Mansouri & Torkestani, 2025; Saleem, 2025). Nevertheless, author-level networks remain fragmented, characterized by small, project-based clusters rather than consolidated research schools, underscoring the field's early developmental stage.

To complement the network visualizations of collaboration patterns, Table 5 summarizes key characteristics of knowledge production and collaboration at the country, institutional, and author levels, offering a consolidated interpretation of global research dynamics.

Table 5. Global collaboration patterns in agentic AI and education research.

Level	Key characteristics	Interpretation
Country	USA and China as central hubs	Concentration of AI capacity
Institution	Interdisciplinary units dominate	Pedagogy embedded in tech
Author	Small, project-based clusters	Early-stage field

Collaboration patterns indicate a globally distributed but uneven research landscape, with limited consolidation at the author level.

5.5. Synthesis of Key Findings

Finally, to explicitly link the empirical bibliometric findings with the conceptual contribution of this study, Table 6 maps key bibliometric patterns onto the dimensions of the APAF, demonstrating how the framework is grounded in observed research trends rather than abstract theorization.

Table 6. Mapping bibliometric findings to the agentic pedagogical agency framework (APAF).

APAF dimension	Bibliometric evidence	Interpretation
Learner Agency	Self-regulated learning, personalization	Shared agency
Teacher Agency	Instructional design, orchestration	Negotiated agency
AI Agency	Autonomous planning, agents, RAG	Delegated agency
Institutional Agency	Ethics, governance, policy	Regulatory mediation

Taken together, the VOSviewer visualizations indicate that agentic AI in education is characterized by rapid technological expansion, increasing pedagogical engagement, and unresolved questions of agency and governance. While applied research increasingly positions agentic systems as co-regulators of learning, theoretical and institutional frameworks capable of systematically integrating these developments remain underdeveloped. These findings provide direct empirical justification for the Agentic Pedagogical Agency

Framework (APAF) proposed in this study, which seeks to align observed bibliometric patterns with a coherent pedagogical understanding of shared, delegated, and negotiated agency in AI-mediated education.

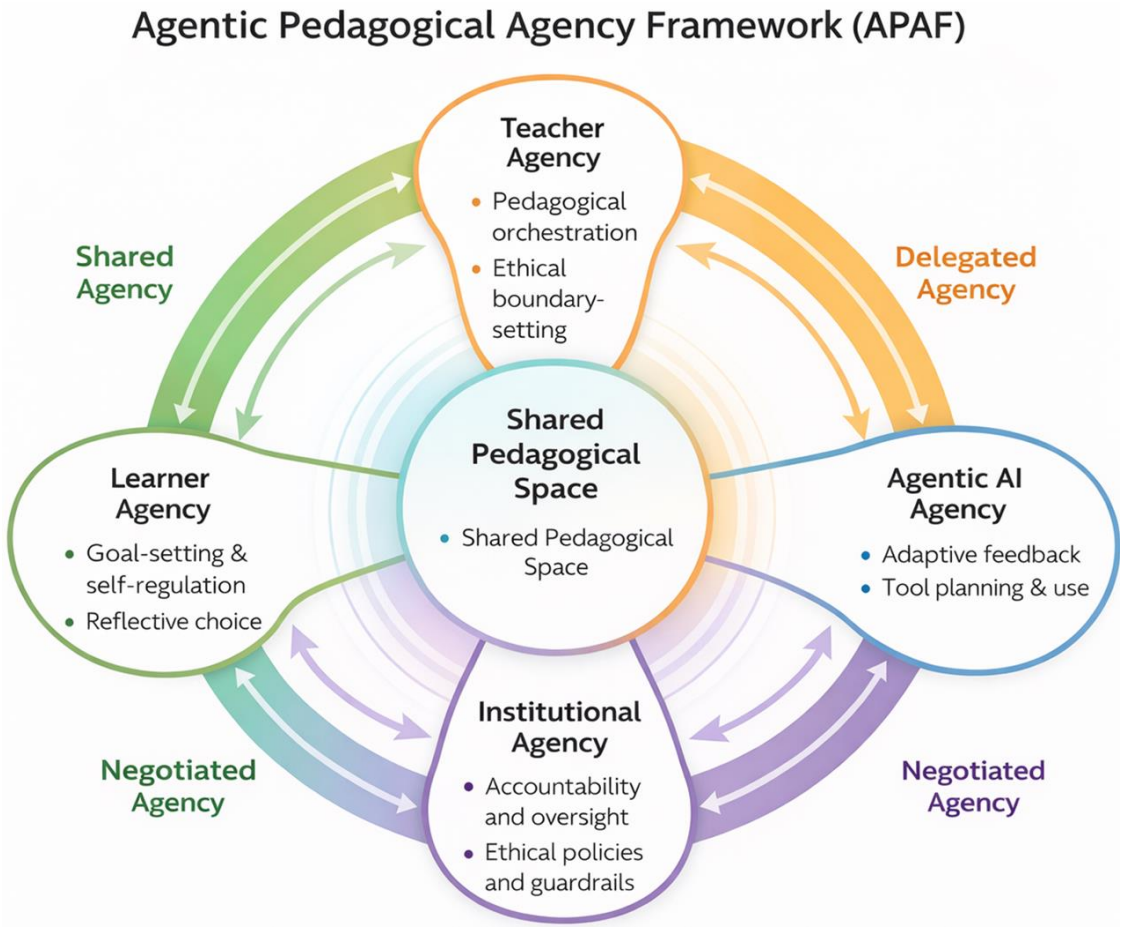

Figure 13. Agentic pedagogical agency framework (APAF).

6. Discussion

The findings of this study provide compelling evidence that agentic artificial intelligence is reshaping educational discourse in ways that extend beyond incremental technological innovation. Rather than functioning solely as an advanced instructional tool, agentic AI emerges as a distributed actor that actively participates in planning, monitoring, and regulating learning processes. This shift fundamentally challenges traditional human-centered models of educational agency and calls for a reconceptualization of how responsibility, autonomy, and pedagogical control are allocated within AI-mediated learning environments.

A key contribution of this study lies in revealing the epistemic divergence between WoS and Scopus representations of agentic AI in education. While WoS prioritizes theoretical legitimacy, ethical foresight, and governance-oriented concerns, Scopus foregrounds pedagogical practice, learner engagement, and applied instructional design. This divergence should not be interpreted as a methodological inconsistency but rather as an indicator of the field's transitional state. Agentic AI appears to be advancing from practice to theory, with educational experimentation and implementation preceding formal theoretical consolidation. Such a trajectory contrasts with earlier waves of educational technology adoption, where theory often preceded large-scale practice.

From a theoretical standpoint, the findings underscore the inadequacy of binary frameworks that position AI either as a neutral tool or as an autonomous replacement for human educators. Instead, bibliometric patterns suggest the emergence of shared, delegated, and negotiated agency as defining characteristics of agentic learning environments. Learners increasingly rely on agentic systems for planning and feedback, educators collaborate with AI agents in instructional orchestration, and institutions embed agentic systems into governance and operational infrastructures. However, these forms of agency redistribution remain largely implicit in the literature, lacking explicit pedagogical articulation or evaluative criteria.

The co-citation and bibliographic coupling analyses further highlight the absence of a unified educational theory capable of integrating agentic AI into existing learning paradigms. While constructs such as self-regulated learning, motivation, and human–AI collaboration appear prominently—particularly in Scopus-indexed research—they are rarely synthesized into a coherent agentic pedagogy. As a result, educational

research risks treating agency as an emergent by-product of technology use rather than as a deliberate design principle. This gap reinforces the need for theory-building efforts that explicitly position agentic AI as a co-regulator of learning rather than a background enabler.

Ethical and governance considerations represent another critical dimension illuminated by the findings. The prominence of trust, accountability, and transparency in WoS literature reflects widespread concern about delegating pedagogical and institutional decision-making to autonomous systems. However, the relative separation of ethical discourse from applied educational research suggests a misalignment between normative principles and day-to-day instructional practice. Without integrative frameworks, ethical guidelines risk remaining abstract, while educational implementations proceed without sufficient critical reflection.

Taken together, these findings position agentic AI as a boundary-crossing phenomenon that destabilizes conventional distinctions between technology and pedagogy, human and non-human agency, and instruction and governance. The challenge for educational research, therefore, is not merely to document agentic AI applications but to articulate how agency should be intentionally designed, distributed, and governed in AI-mediated learning ecosystems.

Precisely because the field is at an early stage, conceptual clarification is necessary before empirical fragmentation becomes entrenched.

APAF is proposed as an analytical and design-oriented framework derived from bibliometric evidence, rather than as an empirically validated instructional model. For instance, in a higher education context, APAF can be operationalized by assigning planning and monitoring functions to agentic AI, while retaining assessment and ethical oversight under teacher and institutional agency.

7. Implications

7.1. Implications for Educational Practice

For educators and instructional designers, the findings highlight the necessity of moving beyond adoption-focused approaches toward agentic learning design. Rather than using AI agents as supplementary tools, practitioners should explicitly define the roles that agentic systems play in planning, feedback, assessment, and learner support. Designing for shared agency requires clear pedagogical intent, transparency about AI decision-making, and mechanisms that allow learners to reflect on and contest AI-generated guidance.

Teacher education programs should incorporate agentic AI literacy as a core competency, emphasizing not only technical proficiency but also pedagogical judgment and ethical awareness. As agentic systems increasingly influence instructional flow, educators must be prepared to act as orchestrators of agency, balancing human expertise with algorithmic support.

7.2. Implications for Institutional Policy and Governance

At the institutional level, the transition toward agentic operational models necessitates robust governance structures that address accountability, oversight, and data stewardship. The preference for human-in-the-loop configurations identified in the literature underscores the importance of preserving human authority in high-stakes educational decisions. Institutions should develop clear policies specifying when and how agentic systems may act autonomously, when human intervention is required, and how responsibility is allocated in cases of system failure or bias.

Furthermore, as agentic AI becomes embedded in student advising, assessment, and administrative workflows, institutions must ensure alignment with emerging regulatory frameworks and ethical standards. Governance strategies should be proactive rather than reactive, integrating ethical considerations into system design rather than treating them as post hoc constraints.

7.3. Implications for Future Research

The findings point to several promising directions for future research. First, there is a pressing need for theoretically grounded agentic pedagogical frameworks that explicitly model the distribution of agency among learners, educators, AI systems, and institutions. Such frameworks should be empirically tested through longitudinal and design-based research to examine how agency negotiations evolve over time.

Second, mixed-methods studies exploring learner and teacher perceptions of agentic systems can provide insight into how trust, autonomy, and responsibility are experienced in practice. Finally, cross-cultural and comparative research is needed to understand how agentic AI adoption varies across educational systems with differing institutional capacities, regulatory environments, and pedagogical traditions.

7.4. Agentic Pedagogical Agency Framework (APAF)

7.4.1. Conceptual Rationale

Building on the bibliometric findings and interpretive synthesis, this study proposes the Agentic Pedagogical Agency Framework (APAF) as a conceptual model for understanding and designing agency in AI-mediated educational environments. The framework responds directly to a key gap identified in the literature: although agentic AI systems increasingly participate in learning processes, existing educational models lack a

coherent structure for articulating how agency is distributed, negotiated, and governed among human and artificial actors.

Rather than treating agency as an attribute possessed exclusively by learners or educators, APAF conceptualizes agency as a relational and dynamic construct that emerges through interaction among four interdependent actors: learners, teachers, agentic AI systems, and educational institutions. This perspective aligns with socio-material and proxy agency theories, while extending them to accommodate autonomous, goal-oriented AI systems capable of sustained pedagogical participation.

7.5. Core Components of the Framework

7.5.1. Learner Agency

Within APAF, learner agency is defined as the learner's capacity to set goals, regulate learning strategies, reflect on progress, and exercise meaningful choice within AI-mediated environments. Agentic AI systems may support learner agency through adaptive feedback, personalized learning paths, and proactive scaffolding; however, such support also introduces the risk of over-delegation, whereby learners defer cognitive and metacognitive responsibility to AI agents. APAF therefore emphasizes calibrated autonomy, in which AI systems augment rather than replace learners' self-regulatory capacities.

7.5.2. Teacher Agency

Teacher agency is reconceptualized as pedagogical orchestration rather than direct instructional control. In agentic environments, educators design learning ecologies in which AI agents operate as co-regulators, assistants, or facilitators. Teacher agency resides in decisions about when and how agentic systems intervene, how feedback is framed, and how ethical and pedagogical boundaries are maintained. This repositioning elevates the educator's role from content delivery to agentic governance and pedagogical judgment.

7.5.3. Agentic AI Agency

Agentic AI is conceptualized not as an autonomous substitute for human actors but as a conditional pedagogical agent whose agency is functionally delegated and normatively constrained. APAF distinguishes between operational agency (Planning, monitoring, tool use) and pedagogical agency (Feedback timing, scaffolding intensity, interaction style). Crucially, the framework asserts that agentic AI agency must remain transparent, explainable, and contestable to preserve human authority and trust.

7.5.4. Institutional Agency

Institutional agency refers to the policies, infrastructures, and governance mechanisms that regulate how agency is distributed across the educational ecosystem. Institutions determine the scope of AI autonomy, enforce accountability structures, and ensure compliance with ethical and legal standards. Within APAF, institutional agency acts as the stabilizing layer that aligns individual and system-level agency with broader educational values and societal expectations.

7.6. Dynamics of Agency Distribution

APAF conceptualizes agency distribution as a continuum rather than a fixed allocation. Educational contexts may shift dynamically between shared agency (Collaborative human–AI decision-making), delegated agency (AI-initiated actions under predefined constraints), and negotiated agency (Human oversight and contestation of AI decisions). These modes are not mutually exclusive and may coexist within a single learning environment, depending on task complexity, learner expertise, and institutional policy.

This dynamic view addresses a critical limitation in current literature, which often treats autonomy as a binary property. By contrast, APAF positions agency as designable, context-sensitive, and ethically governable, offering a practical lens for both research and implementation.

7.7. Implications of the Framework

The Agentic Pedagogical Agency Framework provides a unifying structure for integrating technical, pedagogical, and ethical considerations in agentic AI research. For researchers, APAF offers a theoretical scaffold for empirical studies examining how agency is experienced, negotiated, and redistributed over time. For practitioners, it serves as a design heuristic for aligning AI capabilities with pedagogical intent. For institutions, the framework supports the development of governance models that balance innovation with accountability.

8. Conclusion

This study provides a comprehensive bibliometric and interpretive synthesis of the emerging field of Agentic Artificial Intelligence in Education by comparatively analyzing publications indexed in WoS and Scopus. By integrating keyword co-occurrence, co-citation, bibliographic coupling, and co-authorship analyses, the findings illuminate not only the structural contours of the literature but also the epistemic tenscions shaping how agentic AI is conceptualized, operationalized, and governed within educational contexts.

The results demonstrate that agentic AI is no longer positioned merely as an advanced technological enhancement to learning systems, but rather as an active participant in educational processes that redistributes agency across learners, educators, artificial agents, and institutions. However, this redistribution remains unevenly theorized. While Scopus-indexed literature increasingly foregrounds pedagogical applications, learner autonomy, and human–AI collaboration, WoS literature tends to emphasize technological legitimacy, ethical anticipation, and governance concerns. This divergence reveals a critical conceptual gap: education has yet to articulate a unified agentic framework capable of integrating technical autonomy with pedagogical intent and ethical responsibility.

From a theoretical perspective, the findings suggest that existing educational models—largely grounded in human-centered agency—are insufficient for capturing the complexities introduced by agentic systems capable of independent planning, memory persistence, and goal-oriented action. Agentic AI challenges traditional boundaries between tool use and decision-making, necessitating a reconceptualization of agency as shared, delegated, and negotiated. Without such reconceptualization, educational research risks framing agentic AI either as a neutral efficiency mechanism or as an abstract ethical risk, rather than as a transformative pedagogical actor embedded within learning ecosystems.

At the practical level, the study underscores the urgency for higher education institutions to move beyond ad hoc adoption of agentic technologies toward intentional design and governance strategies. As institutions increasingly transition toward agentic operational models—often described as the "Agentic University"—questions of accountability, transparency, and human oversight become central rather than peripheral. The bibliometric patterns indicate strong stakeholder preference for human-in-the-loop configurations, reinforcing the need for institutional policies that preserve pedagogical authority while leveraging agentic efficiencies.

This study makes three primary contributions. First, it offers the first comparative bibliometric mapping of agentic AI and education across two major citation databases, revealing how indexing logics shape disciplinary narratives. Second, it identifies a clear theoretical and pedagogical gap in current research, positioning education as a field that has yet to reclaim agency as a core analytic construct in AI-mediated learning. Third, it establishes a foundation for future framework development aimed at systematically aligning learner agency, teacher agency, AI agency, and institutional governance.

Despite its contributions, the study is not without limitations. As with all bibliometric analyses, the findings are constrained by database coverage, indexing practices, and language restrictions. Emerging work not yet indexed or published in non-English venues may be underrepresented. Nevertheless, the convergence of patterns across WoS and Scopus lends robustness to the conclusions and supports the validity of the identified trends.

Future research should build upon these findings by developing and empirically validating agentic pedagogical frameworks that explicitly model the distribution of agency within AI-mediated learning environments. Longitudinal studies examining how learners and educators negotiate agency over time, design-based research exploring agentic instructional architectures, and policy-oriented analyses addressing ethical governance will be essential for advancing the field. As agentic AI continues to evolve, education stands at a pivotal juncture: it may either adapt reactively to technological change or proactively shape the principles through which agency, learning, and responsibility are redefined in the age of intelligent systems.

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