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MAPPING THE CONCEPTUAL STRUCTURE OF ARTIFICIAL INTELLIGENCE RESEARCH IN HIGHER EDUCATION

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ABSTRACT

The rapid expansion of artificial intelligence (AI) research in higher education calls for an integrated understanding of its conceptual structure. This study maps the thematic organization of this literature, identifying established research areas and opportunities for further investigation. A corpus of 309 documents published between 2018 and 2026 was compiled from Scopus and Web of Science after duplicate removal. Bibliometrix supported descriptive analysis, country–keyword–institution mapping, and thematic mapping based on author keyword co-occurrence, Louvain clustering, and centrality and density measures. The corpus spans 170 sources and exhibits an annual growth rate of 36.43%. Two motor themes connect AI in education with natural language processing and assessment, and academic integrity with AI and digital literacy. Generative AI, ChatGPT, and large language models constitute central but comparatively less cohesive basic themes. Learning analytics, educational data mining, intelligent tutoring systems, and automated assessment form internally developed niche themes with weaker connections to the broader network. These findings highlight the prominence of assessment, integrity, and literacy alongside technological applications within the retrieved literature. The study identifies opportunities to connect specialized research areas and supports an agenda for longitudinal mapping and empirical evaluation of educational outcomes.

KEYWORDS

Artificial Intelligence in Higher Education, Generative Artificial Intelligence, Bibliometric Analysis

1. INTRODUCTION

Artificial intelligence in higher education (AIHE) is typically situated within the broader field of Artificial Intelligence in Education (AIED), which investigates how computational methods can augment learning, teaching, assessment, and institutional administration. Recent bibliometric evidence indicates that AIED scholarship is disproportionately concentrated in

higher education relative to K-12 settings and is increasingly grounded in machine learning and related techniques (e.g., decision trees, deep learning, speech recognition, and computer vision), with recurring application patterns that include intelligent tutoring systems, learning analytics, recommender systems, automated grading, and educational robotics (Abulibdeh, 2025).

In disciplinary contexts such as computer science, the rapid maturation of AI technologies has stimulated a parallel research stream focused on empirically validated instructional uses (e.g., supporting programming and problem-solving), reflecting the dual imperative of improving learning outcomes and responding to escalating curricular demands in higher education (Cabanillas-García, 2025).

The contemporary AIHE landscape is also shaped by a sharp acceleration in scientific output since 2020 and by a marked shift in the field's conceptual vocabulary. Large-scale bibliometric mapping has documented rapid growth in publications post-2020, alongside an evolution of keywords from artificial intelligence and machine learning toward ChatGPT and ethics, signaling a maturing socio-technical agenda in which technical innovation and normative governance questions are co-evolving (Dogan & Sahin, 2024).

Complementary bibliometric analyses focused specifically on higher education likewise emphasize globalization of the research base and the importance of cross-institutional and cross-national collaboration, with recurring attention to emerging directions such as AI/VR integration, predictive analytics for student performance, and mechanisms to strengthen academic integrity (Ekundayo et al., 2024).

Generative artificial intelligence and large language models (LLMs) have intensified both adoption and controversy in higher education, because their natural-language interfaces enable direct integration into student-facing learning processes (e.g., feedback, drafting, tutoring) and staff-facing workflows (e.g., support services, content generation). Reviews and regional bibliometric studies describe ChatGPT as a prominent focal point of the post-2022 discourse, with reported potential to support personalized, adaptive, and interactive learning experiences, while also elevating concerns about bias, privacy, and responsible use (Fu et al., 2025; Guo et al., 2024).

In parallel, the field increasingly recognizes that educational value is contingent on institutional policy capacity - particularly around acceptable use, assessment redesign, and integrity-preserving pedagogies - rather than on tool availability alone.

Accordingly, current scholarship frames AIHE as a governance-intensive transformation that requires ethical safeguards, AI literacy, and rigorous evaluation across diverse contexts. Systematic and bibliometric reviews identify the growing centrality of ethical implications and the need for AI literacy among educators and students, while also noting persistent gaps in scalability and in evidence about durable impacts across heterogeneous institutional settings (Li & Rohayati, 2025).

Methodologically, qualitative research remains important for capturing human-centered impacts (e.g., changes in instructional practice, student agency, and trust) and for producing context-sensitive accounts of how AI mediates pedagogical and organizational processes (Mahrishi et al., 2024). Beyond the classroom, AIHE is also positioned as an administrative and economic intervention: reviews of AI and ChatGPT in higher education institutions emphasize prospective efficiency gains through process automation and decision-support, including reductions in administrative costs and time burdens for staff and learners (Vorontsova et al., 2025).

Taken together, the literature indicates that AI in higher education is transitioning from a predominantly tool-centric phase to a socio-technical integration phase, where interdisciplinary research, ethical frameworks, and longitudinal evaluation are necessary to realize educational benefits while controlling for risk (Zhu & Zhang, 2025; Zhu et al., 2025).

The current literature positions AIHE as a rapidly expanding socio-technical research domain that has progressed from early, tool-centered implementations (e.g., intelligent tutoring, automated assessment, and learning analytics) toward institution-wide integration concerns that include governance, evaluation, and responsible adoption. Large-scale bibliometric and systematic syntheses indicate a steep increase in publications since approximately 2020, coupled with thematic diversification across pedagogical applications, predictive analytics, and administrative decision support (Abulibdeh, 2025; Dogan & Sahin, 2024). Concurrently, the emergence of generative AI - especially LLM-enabled systems - has reoriented scholarly attention toward human-AI interaction in learning processes and toward policy-relevant issues such as academic integrity, privacy, bias, and ethics (Dogan & Sahin, 2024; Fu et al., 2025; Guo et al., 2024). Evidence from global and higher education focused bibliometric studies further highlights widening international participation and collaboration, suggesting that AIHE research is increasingly shaped by heterogeneous institutional contexts and region-specific implementation constraints (Ekundayo et al., 2024). Within disciplinary subfields (e.g., computer science education), empirical work continues to accumulate on measurable learning impacts and instructional design patterns, underscoring the need to distinguish between proof-of-concept studies and scalable interventions (Cabanillas-García, 2025). Across reviews, the convergence of technological opportunity and normative risk is now widely recognized, with calls for AI literacy, ethical frameworks, and longitudinal impact evaluation (Li & Rohayati, 2025; Mahrishi et al., 2024; Vorontsova et al., 2025 Zhu & Zhang, 2025; Zhu et al., 2025).

Against this backdrop, a suitable research question for a Bibliometrix thematic-map study is: how are the conceptual themes of AIHE structured and which themes function as motor themes, basic themes, niche themes, or emerging/declining themes in the field's conceptual landscape? By answering this question, the article aims to strengthen conceptual consolidation in a rapidly evolving domain and to support a more evidence-aligned agenda for evaluation, governance, and theory development in AI-enabled higher education.

2. METHODOLOGY

The literature search was conducted in the Scopus and Web of Science (WoS) databases using the keyword "artificial intelligence in education." The following filters were applied to the results: document types - articles, proceedings papers, and reviews; and language - English. Subsequently, the keyword "higher education" was added to the search field. Table 1 presents a synthesis of the results obtained at each stage.

The metadata resulting from the two databases were imported and converted using Bibliometrix, an R statistical programming package for science mapping and bibliometric analysis (Aria & Cuccurullo, 2017). Using the Merge Collections function, the two files were combined, and 116 duplicate references were removed, yielding a corpus of 309 metadata records for analysis. Table 2 presents the main indicators of the corpus.

Table 1. Summary of the results of the bibliographic research

Step	Description	Scopus	WoS
1	“Artificial intelligence in education”	2015	848
2	Filters: document types and language	1540	808
3	Add search field: “higher education”	259	166

The dataset encompasses a recent and forward-looking body of literature spanning 2018 to 2026. The inclusion of 2026 may reflect the indexing of early-access or preprint materials. With 309 documents, the corpus is of moderate size, consistent with a focused research domain that is nonetheless sufficiently robust to support bibliometric investigation. The documents are distributed across 170 distinct sources, including journals and proceedings. This dispersion suggests that the topic is not concentrated within a small set of dominant journals but rather disseminated across a broad scholarly ecosystem.

Table 2. Main information about data

Description	Results
Timespan	2018:2026
Sources (Journals, Books, etc)	170
Documents	309
Annual Growth Rate %	36,43
Document Average Age	1,73
Average citations per doc	21,75
Document Contents	
Keywords Plus (ID)	915
Author's Keywords (DE)	851
Authors	
Authors	1072
Authors of single-authored docs	34
Authors Collaboration	
Single-authored docs	34
Co-Authors per Doc	3,73
International co-authorships %	13,92
Document Types	
article	162
conference paper	118
review	29

Indicators of growth and recency point to a highly dynamic research front. An annual growth rate of 36.43% is exceptionally high, and, when interpreted alongside the limited timespan beginning in 2018 and the document average age of 1.73 years, it strongly supports the characterization of this literature as both nascent and rapidly expanding. The low average age

further implies that many publications are concentrated in the most recent years, consistent with accelerated development and heightened research attention.

Authorship and collaboration metrics reinforce the impression of an intensively networked field. A total of 1,072 unique authors contributed to 309 documents, a pattern consistent with broad participation and distributed expertise. The average of 3.73 co-authors per document indicates a strong preference for team-based scholarship, while the limited number of single-authored documents (34, approximately 11% of the corpus) further emphasizes collaboration as a prevailing norm. International co-authorship accounts for 13.92% of publications, reflecting a meaningful level of cross-national partnership. This profile suggests that the field has begun to globalize, with clear potential for deeper international integration as the domain matures.

Citation-based indicators imply unusually strong visibility given the corpus' youth. The mean of 21.75 citations per document is high, particularly considering the 1.73-year average document age. Such a pattern is consistent with rapid uptake by the scholarly community, suggesting that many contributions address timely problems, introduce influential methods, or report findings that are quickly incorporated into subsequent research. While citation behavior varies by discipline, the combination of high average citations and recent publication dates is generally indicative of heightened topical salience and early consolidation of attention around key outputs.

Content descriptors further point to thematic breadth within the broader research area. The presence of 915 Keywords Plus terms and 851 unique author keywords relative to 309 documents indicates substantial conceptual diversification, with multiple sub-themes and specialized topics represented across the corpus. This density of descriptors is advantageous for subsequent mapping of thematic structure, particularly through keyword co-occurrence and trend analyses. Regarding document typology, research articles predominate (162; more than half of the corpus), consistent with an emphasis on reporting original, peer-reviewed findings. Conference papers are also prominent (118; over one third), a pattern typical of fast-moving domains where early dissemination, iterative feedback, and community formation occur through conference venues. The presence of 29 review - type documents is notable in a relatively young field, as it suggests emergent synthesis efforts, early attempts at consolidation, and increasing interest in articulating research trajectories and open problems.

From a data provenance perspective, merging Web of Science and Scopus provides comparatively comprehensive coverage and reduces the risk of database-specific bias, thereby strengthening the descriptive validity of the collection. Overall, the collection depicts a rapidly expanding, and strongly collaborative research domain. Despite its recent emergence, the literature exhibits substantial early impact, broad participation across authors, and dissemination across a diverse set of sources. The distribution of document types suggests a field that is simultaneously producing original contributions, circulating preliminary results through conferences, and beginning to synthesize knowledge via review articles.

3. BIBLIOMETRIC ANALYSIS

The bibliometric analysis examines the conceptual, geographical, and institutional structure of artificial intelligence research in higher education. Based on the merged Scopus and Web of Science corpus of 309 documents, the analysis combines complementary science-mapping

techniques to identify relationships among countries, research themes, and institutions, as well as the positioning and development of thematic clusters. Two analytical perspectives are explored: a three-field plot linking countries, author keywords, and institutions, and a strategic thematic map based on keyword co-occurrence, centrality, density, and Louvain community detection.

3.1 The Three-Field Plot

The three-field plot provides an integrated representation of the relationships among authors' countries (AU_CO), the principal descriptors or themes (DE), and the institutions (AU_UN) responsible for producing the underlying research. In the visualization in Figure 1, bar widths reflect the relative frequency or prominence of items within each field, whereas the thickness of the connecting flows represents the strength of association between elements across fields, such as the extent to which a given country contributes to specific themes or the extent to which particular institutions publish within those thematic areas. Interpreted in aggregate, the plot functions as a compact structural map of geographic participation, topical orientation, and institutional concentration within the dataset.

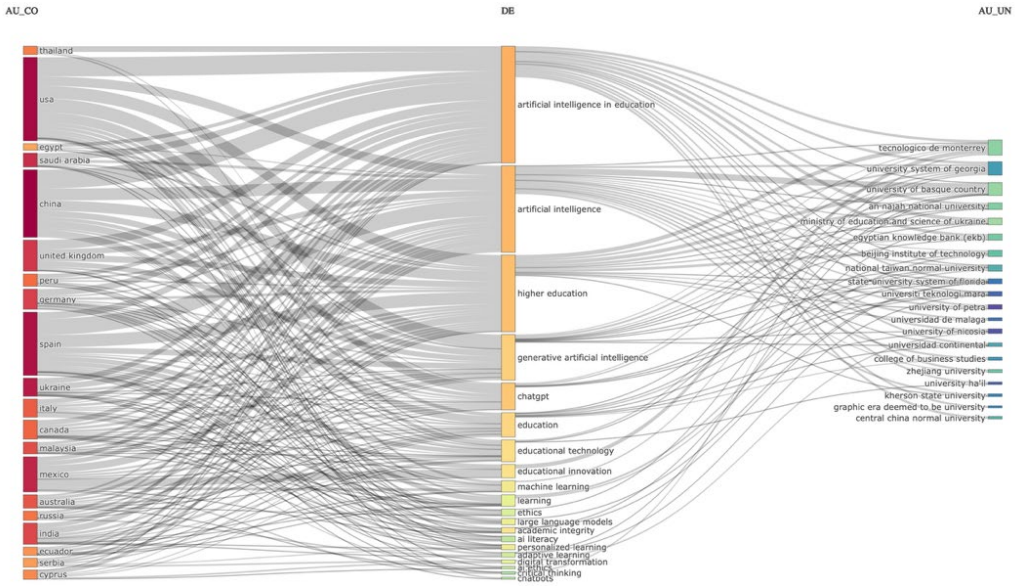

Figure 1. The three-field plot provides an integrated representation of the relationships among authors' countries (AU_CO), the principal descriptors or themes (DE), and the institutions (AU_UN) responsible for producing the underlying research

The overall network architecture indicates a dominant and coherent research flow centered on artificial intelligence and its applications in education. This is apparent from the most substantial linkages emerging from multiple countries and converging on descriptors such as artificial intelligence in education and artificial intelligence, followed by broad dispersion from these themes to numerous institutions. The prominence of AI-related descriptors, particularly those explicitly situated within educational contexts, suggests that the dataset captures a highly

active and collaborative research front characterized by widespread engagement across national and organizational boundaries.

Within the country field, the United States is the most prolific contributor, exhibiting strong connections across multiple high-frequency themes, including artificial intelligence in education, artificial intelligence, and higher education. Mexico, Spain, China, and the United Kingdom also appear as major contributors, each displaying substantial engagement with the core thematic hub centered on AI in education. A broader set of countries - including Ecuador, Malaysia, Australia, Canada, Egypt, Ukraine, India, Russia, Germany, Italy, Thailand, Saudi Arabia, Peru, Cyprus, and Serbia - also participate, though their relative contributions are smaller when assessed by bar width and overall flow magnitude. Collectively, this configuration suggests both concentration among a small number of leading contributors and a meaningful long tail of international participation.

The central descriptor field identifies the thematic structure of the corpus, with artificial intelligence in education serving as the principal hub that mediates a large proportion of country-to-institution linkages. Artificial intelligence constitutes a second major axis, frequently co-occurring with education-specific applications and likely capturing foundational or cross-domain work that informs educational implementations. Higher education is also prominent, indicating sustained attention to university contexts, curriculum design, and pedagogical innovation as key settings for AI adoption and evaluation. These three keywords are the central themes of the research.

Importantly, contemporary descriptors such as generative artificial intelligence and ChatGPT are clearly present and associated with multiple countries and institutions. Although these topics occupy a smaller share of the overall descriptor frequency relative to the more established AI terms, their visible link strength suggests rapid incorporation into the research agenda. Additional descriptors including education, educational technology, educational innovation, machine learning, learning, ethics, large language models, academic integrity, AI literacy, personalized learning, and critical thinking, cluster around the core AI and education nexus, indicating both methodological diversification and growing emphasis on governance, competency development, and learning outcomes.

The institutional field highlights several organizations with disproportionately high research activity. Tecnológico de Monterrey is especially prominent and exhibits strong connections to artificial intelligence in education, suggesting a concentrated institutional focus on this theme. Other highly represented institutions include the University System of Georgia, the University of the Basque Country, An Najah National University, the Ministry of Education and Science of Ukraine, Beijing Institute of Technology, the Egyptian Knowledge Bank (EKB), National Taiwan Normal University, and the State University System of Florida. The breadth of institutions represented across multiple national contexts indicates that investment in this research area is geographically distributed and not confined to a single regional or disciplinary ecosystem.

Several interpretive insights follow from the structure of the flows. First, the dense connectivity between leading countries - particularly the United States, Mexico, Spain, and China - and the descriptor artificial intelligence in education suggests either extensive international collaboration, substantial parallel research activity, or both, centered on a shared thematic agenda. Second, the extensive dispersion from artificial intelligence in education to a wide range of institutions indicates that this theme functions as a primary organizing topic with broad institutional uptake, with Tecnológico de Monterrey standing out as a particularly active locus. Third, the visible connectivity associated with generative artificial intelligence and

ChatGPT indicates an emergent research front that is expanding rapidly across multiple countries and institutions, consistent with accelerated scholarly response to recent technological developments. Finally, the prominence of higher education and its wide connectivity suggest that universities are a key domain of empirical investigation and policy-relevant analysis, encompassing curriculum transformation, instructional practice, and institutional governance under conditions of accelerating AI integration.

3.2 The Thematic Map

The strategic thematic map shows in Figure 2, constructed from author's keywords and clustered using the Louvain community detection algorithm, it positions themes according to relevance (centrality) on the x-axis and development (density) on the y-axis. Centrality operationalizes the extent to which a thematic cluster is connected to other clusters in the network. Themes with high centrality function as integrative, interdisciplinary, or widely influential anchors within the intellectual structure. Density captures the internal cohesion of each cluster, reflecting the strength and maturity of within-theme linkages. Themes with high density typically correspond to well-developed, conceptually coherent research areas. The resulting four-quadrant layout differentiates motor themes (high centrality, high density), niche themes (low centrality, high density), basic themes (high centrality, low density), and emerging or declining themes (low centrality, low density) (Callon et al., 1991).

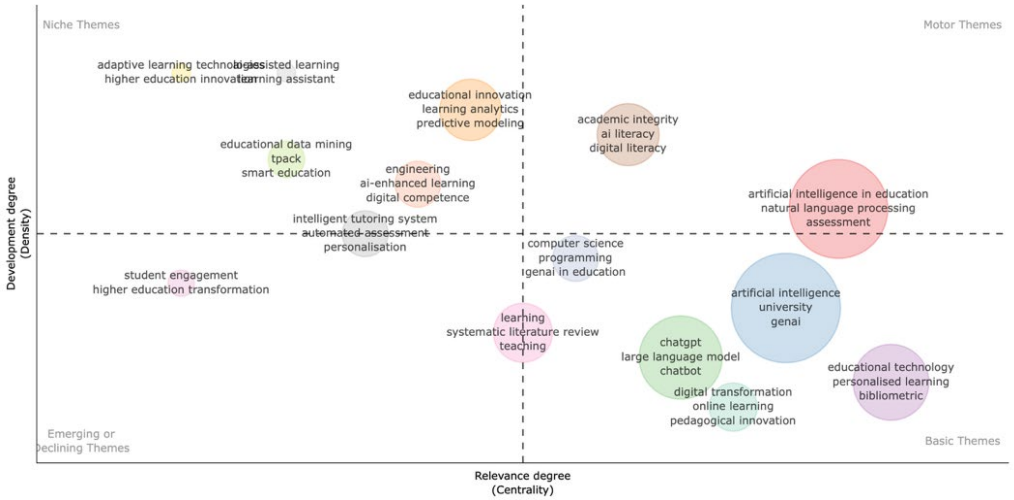

Figure 2. Figure 2. Thematic Map of Authors' Keywords

In aggregate, the map depicts a rapidly evolving research landscape dominated by artificial intelligence and its educational applications, with a notable concentration of highly central contributions dated primarily in 2024–2025 and, in some cases, 2026. This distribution suggests that the thematic structure is being reshaped by a recent acceleration in publication activity and by the diffusion of new AI capabilities into educational research and practice. The prominence of very recent documents among the most central nodes across clusters is consistent with a field undergoing active reconfiguration, in which emerging technologies and associated governance concerns are quickly altering the conceptual agenda.

Within the motor theme quadrant, a major cluster centered on artificial intelligence in education, closely associated with natural language processing and assessment, appears as a dominant, highly cohesive, and highly influential thematic nucleus. Its position indicates both strong internal development and extensive connectivity to other themes, consistent with a mature research stream that also functions as a primary driver of the broader domain. Highly influential and recent publications are concentrated within this cluster, including works by Gago-Galvagno et al. (2025), Mozelius et al. (2024), and Rudolph, Tan and Tan (2023), which collectively suggest sustained attention to language-mediated educational processes and evaluative applications of AI. A second motor cluster organized around academic integrity, AI literacy, and digital literacy similarly exhibits high centrality and high density, indicating a well-developed and field-defining line of inquiry focused on the ethical, behavioral, and competency-related implications of AI deployment in educational settings. The prominence of highly recent and influential works - such as Alzubaidi (2025), Lérias, Guerra e Ferreira (2025), and Kornieva, Baklazhenko, and Lukianenko (2025) - is consistent with the intensification of integrity and literacy concerns following the broad uptake of generative AI tools in learning and assessment environments.

Basic themes in the lower-right quadrant display high centrality but comparatively low density, indicating topics that are widely connected across the field while remaining internally diffuse, heterogeneous, or in an early stage of consolidation. A very large cluster organized around artificial intelligence, universities, and generative AI is exceptionally central, implying that it functions as an overarching conceptual scaffold for multiple subdomains. However, its lower density suggests that the research within this cluster is still coalescing into more coherent substreams, potentially reflecting exploratory work distributed across diverse educational contexts and institutional concerns. The most influential publications in this cluster are recent and highly ranked, including Ismail et al. (2024), Ocak et al. (2025), and Jayasinghe (2024), collectively indicating both high salience and rapid diffusion of university-focused discussions of AI and GenAI.

Closely adjacent, a large cluster focused on ChatGPT, large language models, and chatbots is similarly characterized by high centrality paired with low-to-moderate density, consistent with intense attention to a rapidly emerging technological phenomenon whose applications, theoretical framings, and evaluative approaches remain diverse and in active formation. Key recent influential works include Nguyen et al. (2024), Niño-Carrasco et al. (2025), and Alghazo (2025), reinforcing the interpretation of this theme as a fast-expanding core topic. Another basic-theme cluster connects educational technology, personalized learning, and bibliometric analysis, indicating enduring foundational concepts and infrastructural concerns that remain broadly connected to contemporary AI developments while not forming a tightly bounded, rapidly consolidating specialty (Shumeiko & Osadcha, 2024; Khatib & Mattalo, 2024; Guo et al., 2024). A smaller basic cluster comprising learning (Alam & Mohanty, 2022), computer science (Bandara & Senanayaka, 2024), and digital transformation (Kumar et al., 2025) are consistent with core educational constructs that are widely invoked as contextual foundations across the network rather than developing as a distinct, internally cohesive frontier.

Niche themes occupy the upper-left quadrant and are characterized by strong internal development but weaker integration with the broader thematic network. A cluster emphasizing educational innovation, learning analytics, and predictive modeling shows high density alongside more moderate centrality, suggesting a technically specialized literature in which methodological sophistication is advancing rapidly, albeit within a more bounded subcommunity (Devadason et al., 2025; Lian et al., 2025; Vrbová et al., 2025). Additional niche

clusters focused on adaptive learning technologies (Bharath Yuvaraj & Masilamani, 2024), higher education applications (Al Jadaan et al., 2026), ai-assisted learning, and innovation learning assistant (Boesl & Achtenberg, 2024) exhibit low centrality yet high density, suggesting mature and internally coherent workstreams that may be viewed as specialized implementations rather than general organizing principles of the overall field.

A further niche cluster combining educational data mining, TPACK, and smart education reflects a concentrated research program oriented toward extracting actionable insights from educational data and understanding teacher knowledge frameworks for technology-enhanced learning environments. This cluster includes a mixture of recent contributions, such as Tan, Cheng, and Ling (2025) and Alwakid et al. (2025), alongside an older yet still salient contribution by Wongwatkit et al. (2019), suggesting the presence of earlier foundational work that continues to structure subsequent research in this subdomain. A related, moderately sized niche cluster focusing on intelligent tutoring systems, automated assessment, and personalization is internally robust and actively updated, reinforcing the interpretation of sustained technical advancement within a comparatively specialized thematic perimeter (Abuaisheh & Shuib, 2025; Gao et al., 2025; Mehta et al., 2024).

The last cluster includes engineering, ai-enhanced learning, and digital competence converges on integrating artificial intelligence to strengthen problem-based learning (PBL), experiential learning, and student engagement. A pilot engineering course indicates that AI-enhanced PBL and experiential activities can improve communication competencies and career readiness by scaffolding authentic tasks and reflective practice (Avilés Mariño & Sarasa-Cabezuelo, 2025). A comprehensive review synthesizes how AI can be embedded within online engagement models to support interaction, personalization, and learning analytics in engineering programs (Gupta, 2025). Empirical work further suggests that AI-assisted PBL integration can foster programming proficiency and critical thinking through guided inquiry and timely feedback (Omeh et al., 2025).

Themes located in the lower-left quadrant, low centrality and low density, are plausibly interpreted as emerging, particularly given the overall recency of the dataset, although thematic decline cannot be excluded without longitudinal confirmation. A small cluster focused on student engagement and higher education transformation falls into this quadrant, indicating limited integration with other themes and a still-developing internal structure (Deep et al., 2025; Shen, 2025). Substantively, this cluster appears positioned to grow as institutions seek empirical evidence and conceptual models for maintaining engagement, redesigning learning experiences, and reconfiguring governance and pedagogy under conditions of rapid technological change.

Taken together, the strategic map portrays a field in which AI, especially generative AI and ChatGPT-related technologies, has rapidly assumed a central organizing role, while normative and capability-oriented concerns such as academic integrity and AI literacy have matured into coherent motor themes that are simultaneously well-developed and broadly connected. Specialized technical areas, including adaptive learning, educational data mining, and intelligent tutoring systems, remain internally strong but comparatively niche, suggesting opportunities for increased integration with broader educational research agendas and institutional implementation frameworks. Emerging work on student engagement and higher education transformation appears poised for expansion as the educational implications of AI become increasingly institutional and systemic. Future research can productively focus on isolating mechanisms of impact for GenAI and LLM tools across contexts, designing and evaluating interventions that promote AI literacy and uphold integrity, and identifying pathways by which niche technical solutions can scale into more central, integrative research programs.

Longitudinal stratification of the thematic map by publication year would be particularly informative for distinguishing genuinely emergent themes from transient topics and for assessing whether currently diffuse basic themes are consolidating into denser, more coherent subfields.

4. CONCLUSION

This study delivers an integrated, cross-index bibliometric and thematic mapping of artificial intelligence in higher education (AIHE) research from 2018 to 2026, addressing the lack of consolidated evidence amid rapid publication growth and the diffusion of generative AI (GenAI). Using a merged Scopus–Web of Science corpus (309 documents) and Bibliometrix-based science mapping, the field is characterized as high-velocity yet structurally dispersed (170 sources), with strong expansion (36.43% annual growth), low mean document age (1.73 years), and substantial citation impact (21.75 citations per document), indicating an emergent and rapidly consolidating research front.

Content mapping identifies “artificial intelligence,” “higher education,” and “generative artificial intelligence” as core descriptors, with ChatGPT and LLM-related terms broadly embedded across institutions and countries. The strategic thematic map indicates that AIHE is increasingly organized around governance- and assessment-relevant concerns rather than solely tool-centric applications. A dominant motor theme links AI in education to natural language processing and assessment, reflecting a mature nucleus focused on evaluative and instructional uses. A second highly central and cohesive motor theme centers on academic integrity, AI literacy, and digital literacy, demonstrating that normative and capability-oriented issues have become field-defining.

The analysis also highlights maturity constraints and research opportunities. A central but moderately cohesive cluster on ChatGPT/LLMs/chatbots suggests rapid uptake with incomplete conceptual consolidation. Several niche clusters—learning analytics and predictive modeling, educational data mining and smart education, intelligent tutoring and automated assessment, and engineering-oriented AI-enhanced learning—are internally robust yet weakly integrated, indicating potential for synthesis and scaling. Methodological limitations include harmonization risks in merged databases and incomplete cited-reference metadata that may bias citation-network metrics.

Future research should prioritize mechanism-focused studies on learning and assessment effects, rigorous interventions to build AI literacy while safeguarding integrity, and pathways to integrate niche technical solutions into governance-aligned, longitudinal research programs.

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