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A MIXED METHODS MAPPING OF AI AND LLM ENHANCED LANGUAGE LEARNING RESEARCH IN HIGHER EDUCATION FROM 2008 TO 2025

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Abstract:
Artificial intelligence (AI), especially large language models (LLMs), is increasingly transforming higher education, offering opportunities for personalized learning, adaptive assessment, and innovative instructional design. This study maps research on AI- and LLM-Enhanced Language Learning in higher education (AIHEd) from 2008 to 2025, using bibliometrix, structural topic modeling (STM), and VOSviewer network analyses. With bibliometric analyses, publication results show modest production before 2015, steady growth from 2016 to 2022, and a sharp surge after 2023, peaking at 1,078 articles, reflecting accelerating interest in AI and LLMs in higher education. Research articles are mainly published in journals such as *Education and Information Technologies*, *BMC Medical Education*, and *Interactive Learning Environments*, with institutions including Monash University and the University of Hong Kong serving as major collaboration hubs. China leads in total output, while the US and UK demonstrate higher per-article impact. Highly cited studies published in 2023–2024 cluster around generative AI, learning analytics, and educational technology. Keyword analyses reveal a clear thematic progression from foundational AI (2008–2013), to data-driven and personalized learning (2014–2019), and to generative AI applications (2020–2025). STM identifies eight latent topics spanning technical development and learner-centered pedagogy. VOSviewer co-occurrence networks further reveal four major clusters, namely, technological innovation, pedagogical integration, ethical and policy issues, and AI literacy and adoption, highlighting the growing prominence of ethical and responsible AI use alongside technological advancement. By mapping publication trends, thematic structures, and collaboration networks, the findings provide actionable guidance for policymakers, institutions, and educators in curriculum development, research planning, and ethical decision-making in AIHEd.

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Keywords: AI, higher education, bibliometrix, STM, VOSviewer

1. Introduction

Research on artificial intelligence (AI) in higher education has expanded rapidly after 2018, with a sharp increase following the public release of ChatGPT in 2022. A few scoping reviews document how AI has been applied to teaching, learning, assessment, and institutional strategy (Zawacki-Richter, 2019; Chen *et al.*, 2022; Chu *et al.*, 2022; Ouyang *et al.*, 2022; Crompton, 2023; Bond *et al.*, 2024; Biagini, 2025). AI is also discussed in relation to discourses, strategic planning, and policy alignment (Bearman *et al.*, 2023; Abulibdeh *et al.*, 2025; Barus *et al.*, 2025). Reviews also map the global distribution and thematic focus of AI research in higher education in Latin America, Europe, etc. (Salas-Pilco & Yang, 2022; Stracke *et al.*, 2025). While these reviews provide valuable overviews, they typically have limited attention to language learning as a distinct area of inquiry.

Other literature focuses on generative AI (GenAI) and large language models (LLMs), especially ChatGPT. Reviews examine uses of LLMs for academic skills development and feedback (Ansari *et al.*, 2024; Daniel *et al.*, 2025; Jensen *et al.*, 2025). Studies on chatbots and conversational agents highlight their potential to support interaction, practice, and formative feedback in higher education (Lambebo & Chen, 2025; Ma *et al.*, 2025; McGrath *et al.*, 2025).

Despite the steady expansion of scholarship on AI in higher education, AI- and LLM-enhanced language learning research remain underexplored due to the scope and design choices of earlier studies. Many existing reviews adopt narrative or thematic synthesis approaches, which are well suited to clarifying concepts and summarizing emerging practices but are less able to capture long-term patterns, relational structures, or thematic evolution. In addition, some reviews focus on publications before 2022 or on selected highly cited studies, reflecting practical limitations in addressing the rapidly growing literature.

Building on this foundation, the present study maps AI- and LLM-enhanced language learning research in higher education with more recent data from 2008 to 2025 using a mixed-methods approach. By combining bibliometric analysis, keyword network analysis, and qualitative interpretation through Bibliometrix, related RStudio packages, and standalone VOSviewer, the study provides a structured overview of publication trends, thematic development, and research networks of AIHEd. In this context, the study addresses the following three research questions:

RQ1: What are the publication characteristics, scholarly impact, and collaboration patterns of AIHEd between 2008 and 2025?

a) annual publication trends over time;
b) the most productive and influential journals;
c) leading authors based on productivity and citation indicators;
d) the most productive institutions;
e) country-level research output;

f) patterns of single-country and multi-country publications and country-level citation impact;
g) institutional collaboration networks and central hubs;
h) the thematic focus of the most highly cited articles during the period; and
i) the evolution of research focus in AIHEd.

RQ2: What are the dominant research topics and how have thematic emphases in AIHEd evolved over time?

a) the latent topics as identified through STM; and
b) the evolution of these topics across three periods.

RQ3: How do keyword co-occurrence networks reveal the conceptual structure and emerging priorities of AIHEd?

a) the major thematic clusters and their interrelationships identified through VOSviewer co-occurrence analysis; and
b) the prominence of themes in 26 highly cited articles.

2. Research Methodology

Data for this bibliometric study were retrieved from the Web of Science Core Collection on January 1, 2026[ii]. An advanced search was conducted using the Boolean string:

TS=("artificial intelligence" OR "machine learning" OR "deep learning" OR "neural network*" OR "large language model*" OR LLM* OR "generative AI" OR "generative artificial intelligence" OR ChatGPT OR "GPT-3" OR "GPT-4" OR "natural language processing" OR NLP OR "intelligent tutor*" OR "adaptive learn*" OR "personalized learn*" OR "learning analytic*" OR "educational data mining" OR "AI-assisted learning" OR "AI-powered education") AND TS=(learn* OR teach* OR educat* OR instruction* OR pedagogy* OR assessment* OR "language learning" OR "second language" OR EFL OR ESL OR "foreign language*" OR "second language acquisition") AND TS=("higher education" OR universit* OR college* OR undergraduate* OR postgraduate* OR "bachelor*" OR "master*" OR "PhD student*" OR "PhD candidate*") NOT TS=("secondary school*" OR "high school*" OR "middle school*" OR "K-12" OR K12 OR "primary school*" OR "elementary school*" OR kindergarten* OR child* OR adolescen*) AND PY=(2000-2026)

To ensure relevance and quality, the search was refined to English-language publications classified as articles only, and limited to the Education: Educational Research category. After deduplication and screening for relevance, the resulting dataset

[ii] Note: Owing to the inherent indexing lag of bibliographic databases, the dataset for 2025 is incomplete, as some articles published late in that year may not yet have been indexed at the time of retrieval. Conversely, a small number of records indexed in early 2026 but assigned a publication year of 2025 may be included. This is a common feature of longitudinal bibliometric analyses and does not compromise trend analyses for the fully indexed period (2008–2024) or the interpretable patterns observed in the indexed subset of 2025 publications.

of 2,469 articles was exported in full record and cited references format for a mixed-methods approach combining descriptive, relational, and thematic analyses.

Prior to analysis, keyword normalization was performed to reduce noise caused by terminological variation. Specifically, singular and plural forms, acronyms and their full expressions, and widely accepted synonymous terms (e.g., AI and artificial intelligence; flipped classroom and flipped learning) were merged into unified conceptual labels. This procedure follows standard bibliometric preprocessing practices and aims to improve network clarity, co-occurrence accuracy, and interpretability. Keywords representing different levels of abstraction or substantively different concepts were intentionally retained as separate nodes to preserve analytical rigor.

First, the dataset was analyzed using bibliometrix (R) in RStudio (Build 392) to examine annual publication trends, most prolific journals, authors' productivity and impact measured by citation metrics such as the H-index and total citation, contribution of countries and institutions, geographical distribution patterns of corresponding authors and international collaborations, major countries as contributors, university collaborations, articles of highest citations, and most frequently used author keywords in each period.

Secondly, analyses were conducted using dplyr, tidyr, stringr, and ggplot2 in R. Preprocessing removed non-informative terms and standardized keywords. Compound concepts (e.g., intelligent tutoring systems, deep learning, learning analytics, generative AI, personalized learning) were merged and treated as single units. Keywords were analyzed across three periods (2008–2013, 2014–2019, 2020–2025) using absolute frequencies. STM was applied by training multiple LDA models, evaluating coherence scores, and selecting the optimal model. Faceted horizontal bar charts with labeled frequencies were used to visualize temporal trends and enable cross-period comparison. Thirdly, VOSviewer and keyword co-occurrence networks are used to identify main research themes, emerging topics, and their interconnections. It visualizes the conceptual structure, tracks thematic evolution over time, highlights research hotspots, and reveals underexplored areas, providing a data-driven basis to understand field development and guide future AI- and LLM-enhanced language learning research. Thus, the integration of bibliometric analysis, STM, and VOSviewer offers a triangulated approach, enabling a multi-dimensional exploration of AIHEd.

3. Results and Discussion

3.1 Publication Characteristics, Scholarly Impact, and Collaboration Patterns (RQ1)

RStudio provides a flexible and reproducible environment for bibliometric and text-based analyses (Kronthaler & Zöllner, 2021). Bibliometric analysis can be used as a systematic and reproducible means of quantifying research productivity, impact, and thematic trends, making it well suited for large-scale overviews of a research field (Aria & Cuccurullo, 2017; Sánchez *et al.*, 2022; Pradana, Elisa & Syarifuddin, 2023; Polat *et al.*, 2024; Ghazali *et al.*, 2025).

Figure 1 shows the annual publication trends in AIHEd. Research output was modest before 2015, increased steadily from 2016 to 2022, and surged sharply in 2023–2025, reaching a peak of 1,078 articles in 2025. This trend highlights the rapidly expanding interest in AI applications, particularly in the context of higher education.

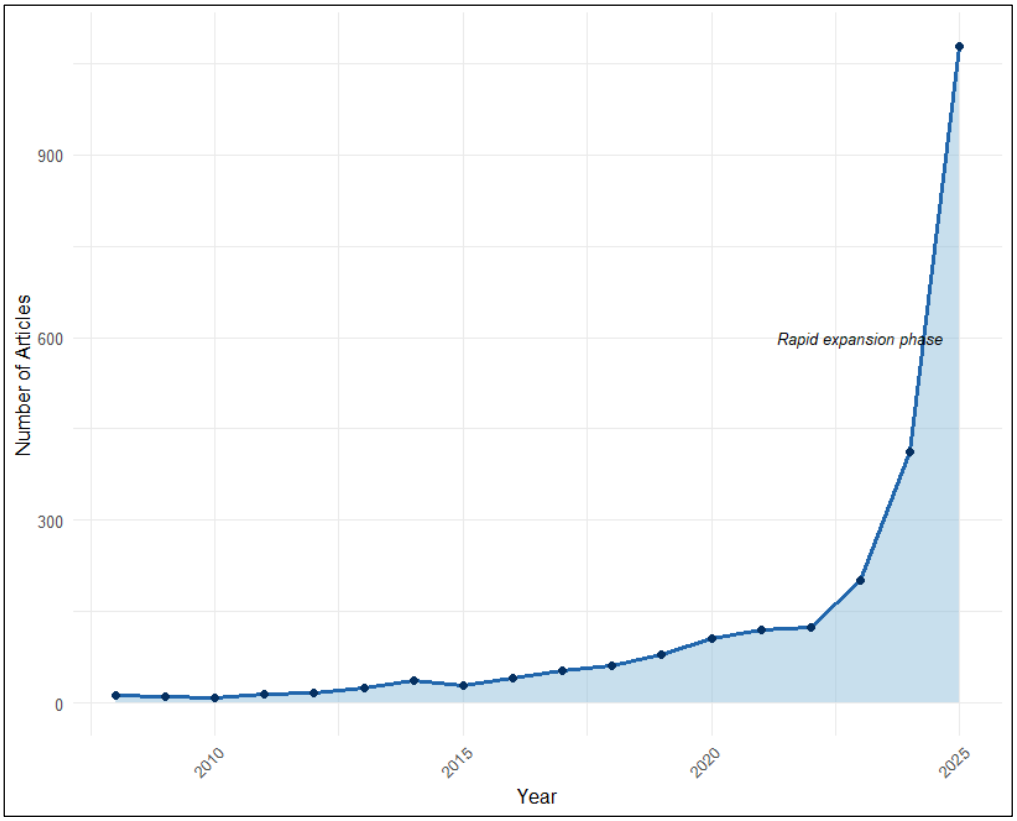


Figure 1: Annual growth of AIHEd publications (2008-2025)

As shown in Figure 2, publications on AIHEd are concentrated in journals led by Education and Information Technologies (344 articles), followed by BMC Medical Education (149) and Interactive Learning Environments (129). Core educational technology journals such as Computers & Education (112), International Journal of Educational Technology in Higher Education (110), and British Journal of Educational Technology (87) account for a substantial share. Several higher education–focused journals (e.g., Assessment & Evaluation in Higher Education, Studies in Higher Education, Higher Education) also appear.

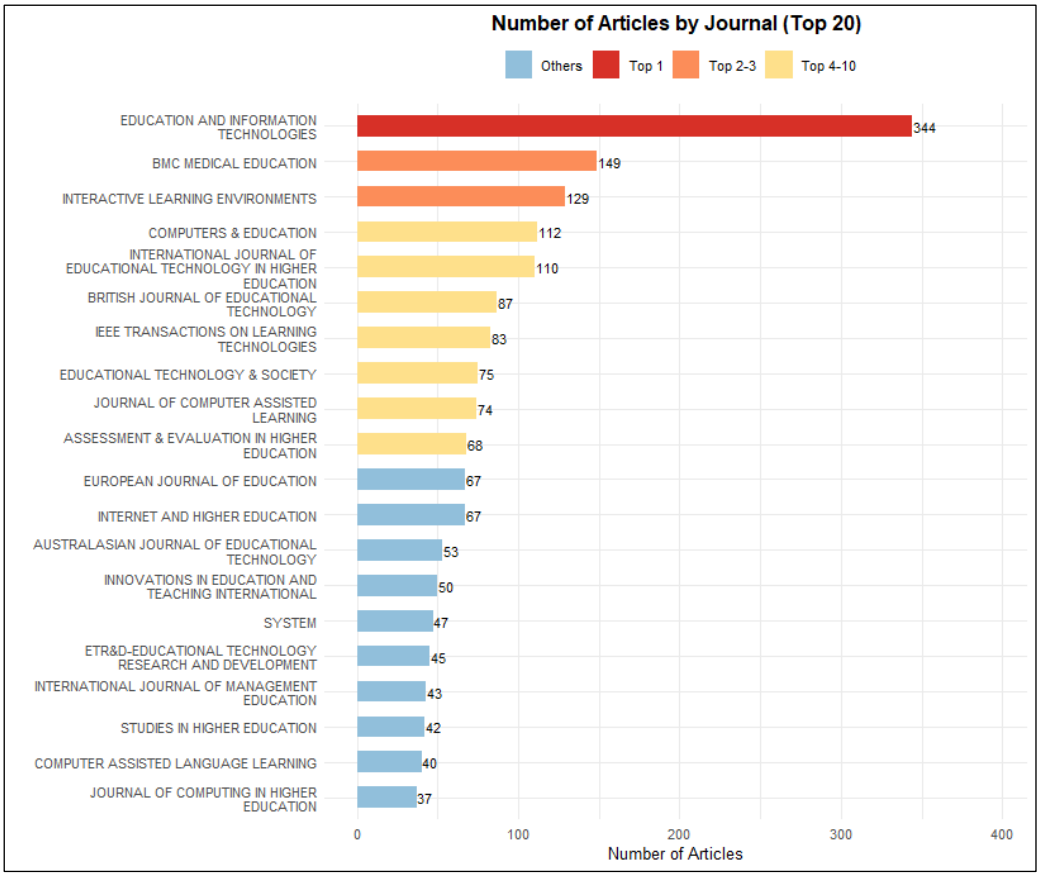


Figure 2: Number of articles by journal (Top 20)

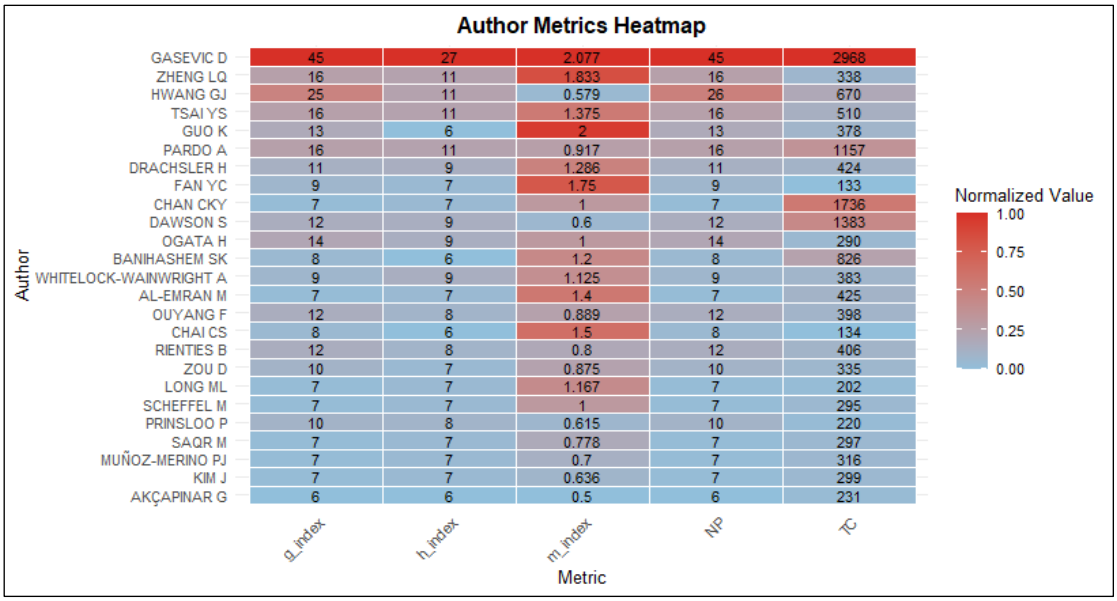


Figure 3: Author metrics heatmap

Figure 3 summarizes the leading authors in AIHEd research using multiple bibliometric indicators, including g-index, h-index, m-index, number of publications (NP), and total citations. The results reveal marked disparities in scholarly impact and productivity. Gasevic stands as the most influential author, with the highest h-index (27),

g-index (45), total citations (2,968), and publication output (45), accompanied by a high m-index (2.077). A group of authors are with comparable h-indices (e.g., Zheng, Hwang, Tsai, Pardo). Several authors such as Chan, Dawson, and Pardo have relatively low publication counts, nevertheless exhibiting substantial citation influence. Among them, Chan's seven publications have accrued 1,736 citations.

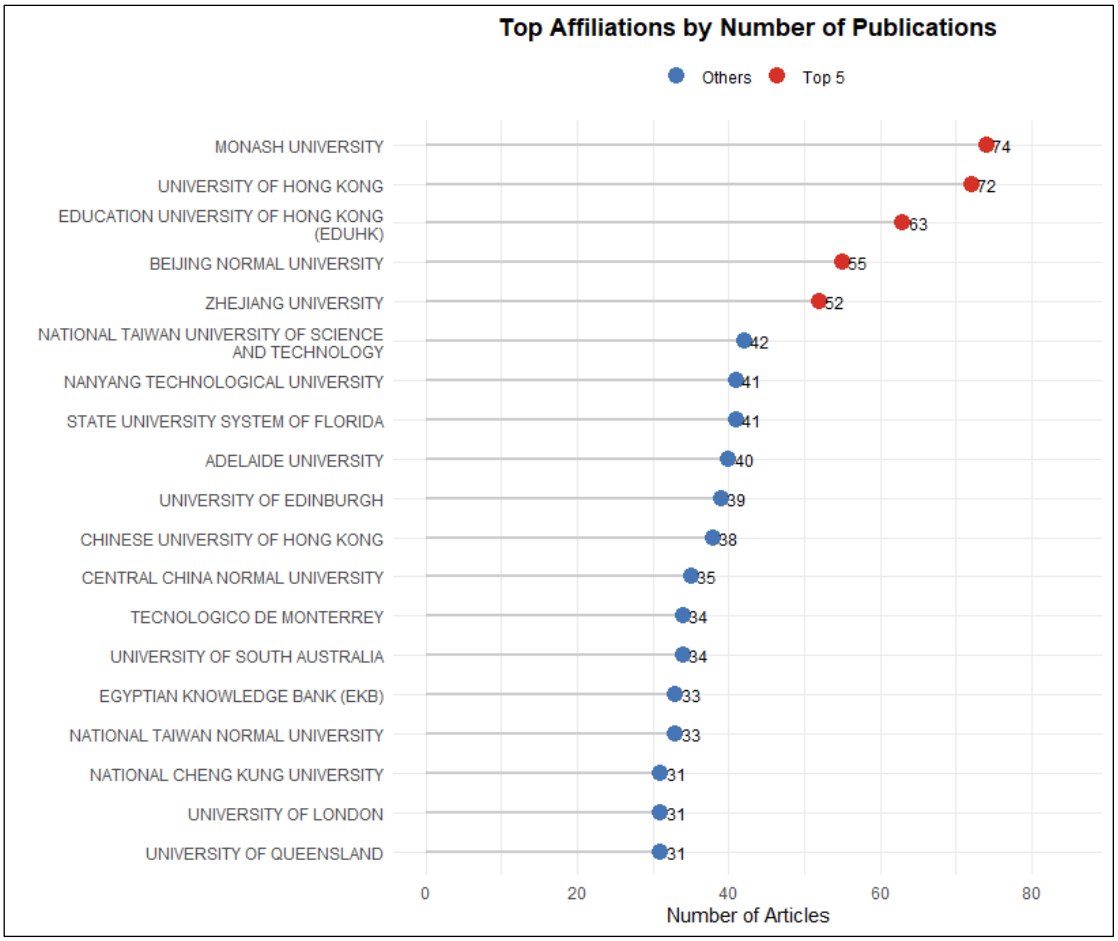


Figure 4: Top affiliations by number of publications

Figure 4 shows that Monash University has the highest output with 74 articles, followed closely by the University of Hong Kong (72) and the Education University of Hong Kong (63). Beijing Normal University (55) and Zhejiang University (52) are the leading contributors from mainland China. Multiple institutions contribute between 40 and 42 articles, including the National Taiwan University of Science and Technology, Nanyang Technological University, the State University System of Florida, and the University of Adelaide. The remaining institutions in the top group each produced 31–39 articles.

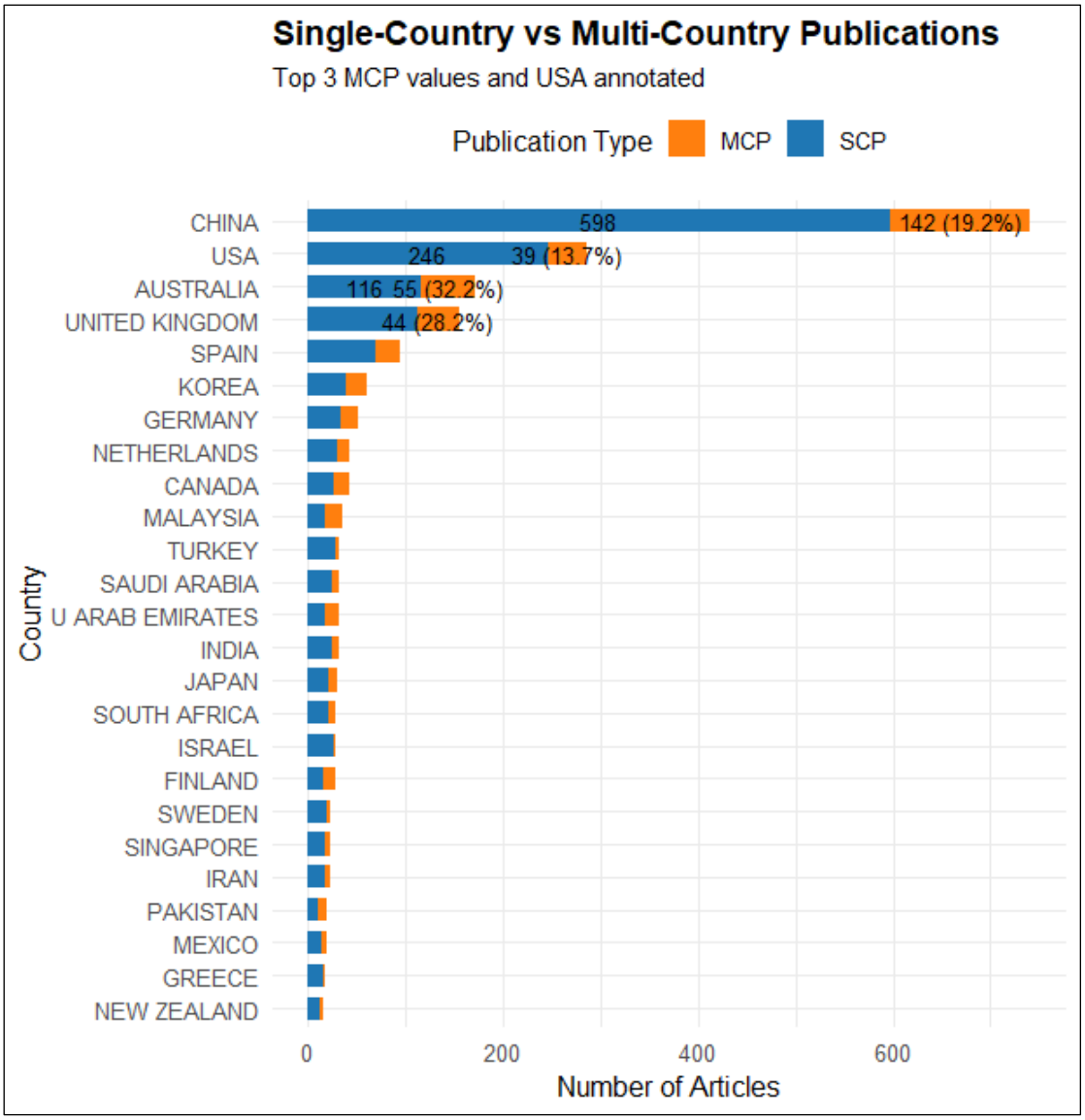


Figure 5: Corresponding author's countries and collaboration structure

Figure 5 illustrates the distribution of single-country publications (SCP) and multi-country publications (MCP) across leading research countries. China leads in total output (740 articles), followed by the USA (285) and Australia (171). The stacked bars show that while China produces the most articles, its proportion of MCP is relatively smaller (19.2%), whereas countries such as Australia (32.2%), and the United Kingdom (28.2%) have higher MCP percentages, reflecting stronger international collaboration.

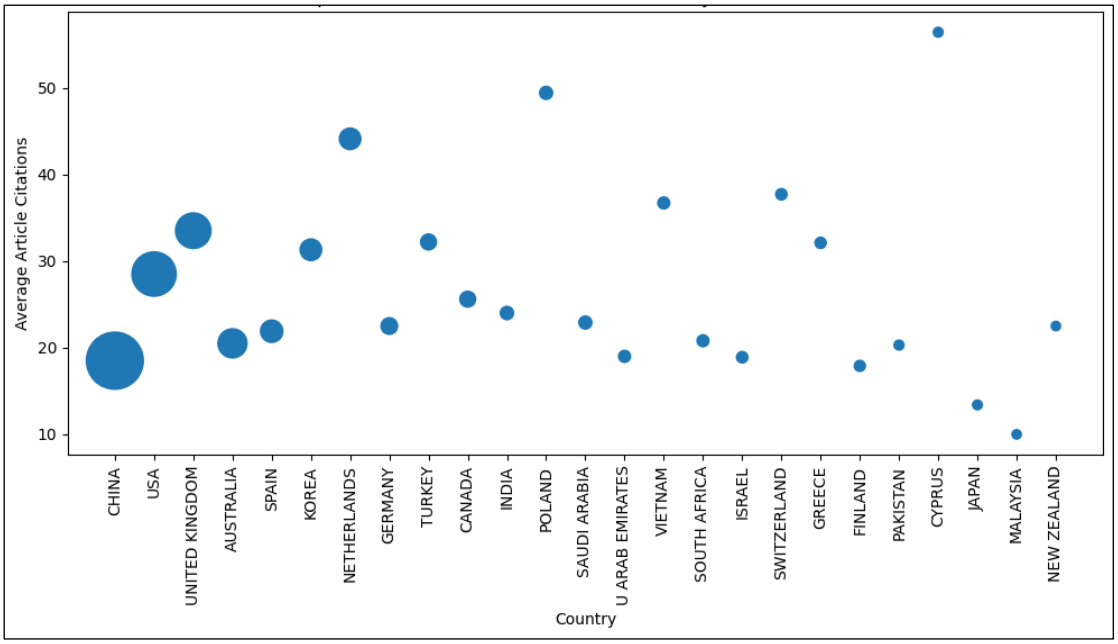


Figure 6: Impact profile of countries: citation intensity vs total citations

As shown in Figure 6, China leads in total citation volume, indicating the largest aggregate research output, while the US and the UK show substantially higher average citations per article, reflecting stronger per-paper impact. Several smaller or mid-sized contributors, including Cyprus, Poland, and the Netherlands, achieve the highest average article citations despite comparatively low total citation counts. Countries such as Korea, Greece, and Vietnam also demonstrate relatively high per-article impact. In contrast, Japan and Malaysia exhibit the lowest average citation rates, suggesting more limited citation influence per publication within the dataset.

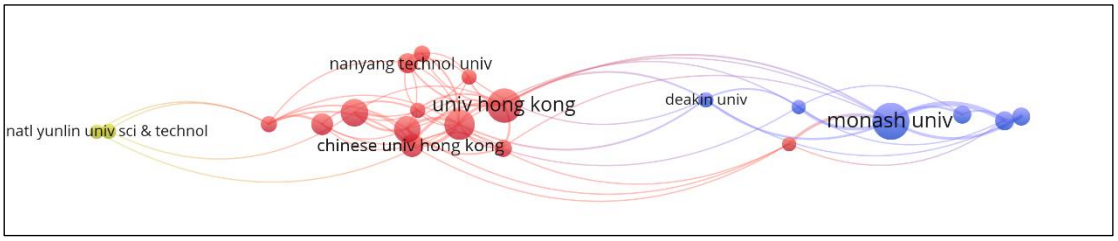


Figure 7: University collaboration

From an institutional perspective, Figure 7 demonstrates that Monash University, the University of Hong Kong, and the Education University of Hong Kong emerge as central hubs of collaboration. Several Chinese universities, including Peking University and the Chinese University of Hong Kong, have also established substantial academic partnerships, highlighting the growing interconnectedness between Chinese and international institutions in AIHEd research.

Table 1: Top-10 most cited articles published in 2023 and 2024

No.	Articles	Total Citations
1	Cotton, 2024, INNOV EDUC TEACH INT	1035
2	Chan, 2023, INT J EDUC TECHNOL H	813
3	Farrokhnia, 2024, INNOV EDUC TEACH INT	626
4	Crompton, 2023, INT J EDUC TECHNOL H	523
5	Chan, 2023, INT J EDUC TECHNOL H-A	509
6	Strzelecki, 2024, INTERACT LEARN ENVIR	406
7	Chiu, 2024, INTERACT LEARN ENVIR	389
8	Walter, 2024, INT J EDUC TECHNOL H	305
9	Huang, Lu, Yang, 2023, COMPUT EDUC	286
10	Adeshola, Adepoju, 2024, INTERACT LEARN ENVIR	271

The majority of the most cited articles between 2008 and 2025 were published in 2023 and 2024. They cluster around three main themes: generative AI in education, learning analytics, and broader educational technology research. Among them, four highly cited works focus specifically on generative AI tools such as ChatGPT and their impact on higher education. For example, Cotton (2024) examines issues of academic integrity in the era of AI-assisted writing, Farrokhnia *et al.* (2024) analyzed ChatGPT's implications for education, while Chan (2023) develops a comprehensive policy framework for AI integration in university teaching and learning. Another article by Chan (2023a) investigates student perceptions of generative AI, including both benefits and challenges. Walter (2024) addresses similar themes of AI adoption and institutional response. Three articles focus on learning analytics. Strzelecki (2024) and Chiu (2024) contribute to understanding how educational technologies, including AI, affect student engagement, assessment, and instructional design. Adeshola and Adepoju (2023) provide methodological insights into interactive learning environments. Huang, Lu, and Yang (2023) represent the broader educational technology research strand, examining the integration of AI and learning technologies in instructional contexts, bridging technology, pedagogy, and student outcomes.

In RStudio, packages like dplyr, tidyr, and stringr enable rapid data wrangling and keyword consolidation, while ggplot2 allows precise, publication-ready visualizations. As shown in Fig. 8, analysis of the author keywords reveals a clear evolution of research focus in AIHEd over the three periods, revealing a progression from foundational AI and educational technology applications (2008–2013), to data-driven pedagogy and personalized learning (2014–2019), and finally to the generative AI era (2020–2025).

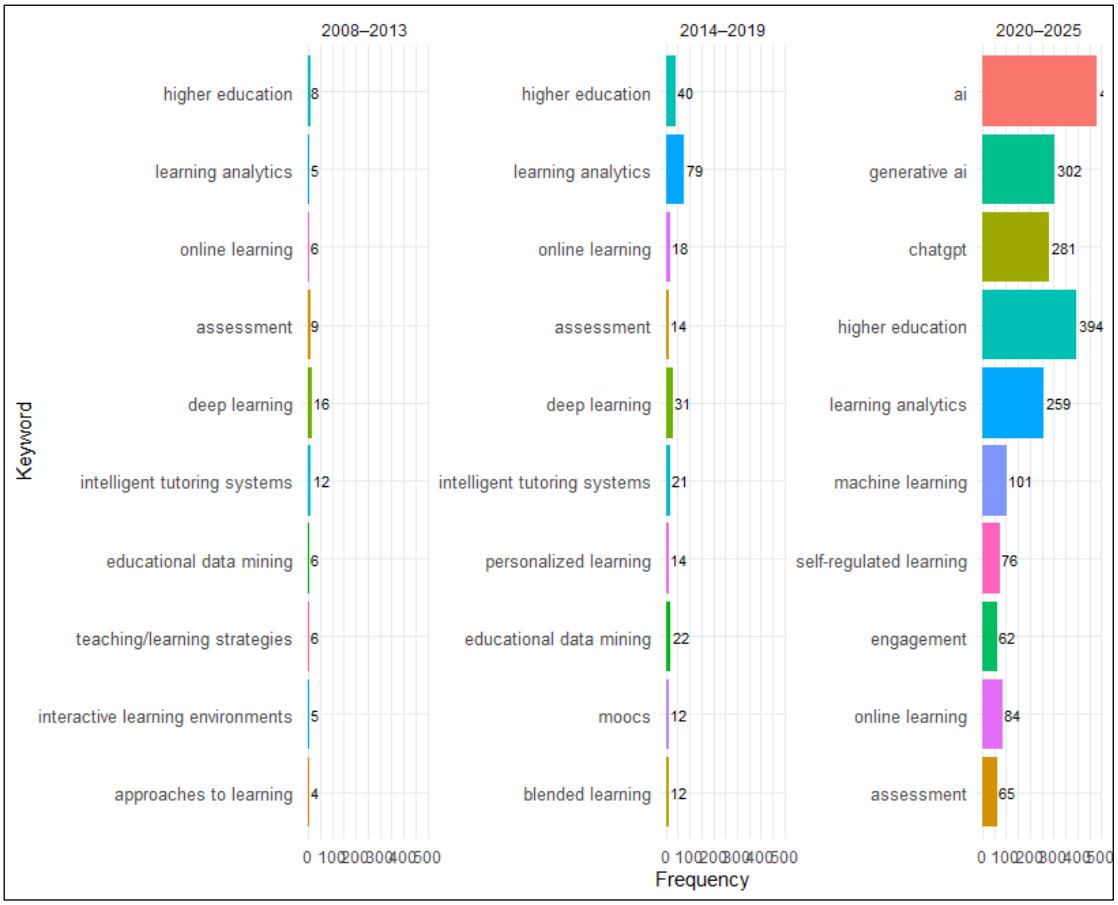


Figure 8: Top 10 author keywords by period (Absolute Count)

During 2008–2013, the most frequent keywords were deep learning (16 occurrences), intelligent tutoring systems (12), assessment (9), and higher education (8). Other notable terms included educational data mining, online learning, teaching/learning strategies, interactive learning environments, learning analytics, and approaches to learning. It suggests that early research focused on foundational AI-driven educational technologies, assessment strategies, and the design of interactive and online learning environments. The relatively low frequencies indicate the nascent stage of AI adoption in AIHEd research.

In 2014–2019, there was a marked shift toward data-driven and personalized learning. Learning analytics became the most frequent keyword (79 occurrences), followed by higher education (40), deep learning (31), educational data mining (22), and intelligent tutoring systems (21). Other significant keywords included online learning (18), assessment (14), personalized learning (14), blended learning (12), and MOOCs (12). This period reflects a growing emphasis on leveraging educational data for personalized and adaptive instruction, as well as supporting scalable digital education platforms.

The period 2020–2025 shows a dramatic rise in AIHEd, highlighted by AI (481 occurrences), generative AI (302), ChatGPT (281), and learning analytics (259). Other frequently occurring keywords include machine learning (101), online learning (84), self-regulated learning (76), assessment (65), and engagement (62). These data indicate the

rapid integration of generative AI technologies into higher education research and pedagogical practices. Traditional topics, such as assessment, online learning, and higher education, remain important, but the focus has shifted decisively toward AI-enabled tools, generative AI, and strategies to enhance student engagement.

3.2 Dominant Research Topics and Thematic Evolution (RQ2)

Structural Topic Modeling (STM) offers distinct advantages in uncovering the latent thematic structure of textual corpora (Kuhn, 2018; ElSayary and Mohebi, 2024). By modeling topics as probabilistic distributions of words, STM enables the identification of coherent research themes that may not be apparent through keyword counts or citation-based indicators alone.

3.2.1 Eight Latent Topics

In the STM analysis, the optimal number of topics was determined to be 8, yielding the highest coherence score. The identified 8 topics are:

a) Learning environment & educational technology;
b) LLM & medical education;
c) Learning analytics, higher education & teaching with ChatGPT;
d) Language learning & instructional design;
e) Digital education, research & student factors;
f) Learning systems in Asian contexts;
g) Academic performance & course feedback;
h) Collaborative learning & knowledge building approaches.

a) Topic 1: Learning environment & educational technology

Studies related to this topic have examined emerging digital and AI-supported learning environments from the perspectives of learner acceptance, self-regulation, and instructional effectiveness. Di Natale *et al.* (2024) investigated students' acceptance and continuance intention toward immersive virtual reality and metaverse-integrated learning in an Italian university course, demonstrating that perceived usefulness, enjoyment, and social presence significantly influenced sustained adoption. In the same year, Lee *et al.* (2024) explored ChatGPT with an embedded guidance mechanism in blended learning, finding that structured AI support enhanced self-regulated learning, higher-order thinking skills, and collaborative knowledge construction, while reducing superficial AI dependence. Extending the focus to institutional and behavioral dimensions, Lin *et al.* (2025) analyzed teachers' switching intentions in online teaching during the COVID-19 era using a push–pull–mooring framework, revealing that technological pressure, pedagogical benefits, and contextual constraints jointly shaped instructional continuity decisions. Shahzad *et al.* (2025) examined generative AI technologies in higher education and reported that learning performance was indirectly influenced by self-efficacy, creativity, trust, and perceptions of fairness and ethics. Wang *et al.* (2025) demonstrated that ChatGPT-integrated feedback aids within virtual reality

environments significantly improved students' self-regulated learning and higher-order thinking skills.

b) Topic 2: LLM & medical education

Recent scholarship on this topic has examined the application of large language models (LLMs) in medical education. Grévisse (2024) investigated LLM-based automatic short-answer grading in undergraduate medical education, demonstrating substantial efficiency gains and acceptable agreement with human graders, while emphasizing the need for oversight in borderline cases. Building on assessment-oriented research, Elzayyat, Mohammad, and Zaqout (2025) compared LLM-generated and expert-created multiple-choice questions in clinical anatomy, finding that students perceived AI-generated items as comparable in clarity and difficulty, though expert-authored questions were regarded as more contextually nuanced. Kiyak *et al.* (2025) explored the use of LLMs to generate key-feature questions and reported promising structural validity, alongside concerns regarding clinical authenticity. Focusing on content knowledge, Mavrych *et al.* (2025) conducted a cross-platform evaluation of LLM performance in medical education on histological questions, revealing notable variability across models and question types. Complementing these findings, Mishra, Lurie, and Mark (2025) assessed LLM accuracy using a concordance test with medical teachers, concluding that while LLMs show educational potential, their outputs require systematic validation before high-stakes use.

c) Topic 3: Learning analytics, higher education & teaching with ChatGPT

Current literature on Topic 3 illustrates the integration of AI-generated feedback and learning analytics in higher education. Banihashem *et al.* (2024) compared peer-generated and AI-generated feedback in essay writing, finding that while AI feedback improved clarity and structure, peer feedback better supported critical thinking and reflective learning. Chen and Chang (2024) investigated AI-assisted game-based learning in science education, demonstrating enhanced learning outcomes and intrinsic motivation, along with reduced cognitive load and improved engagement behaviors. Ouyang *et al.* (2024) examined instructor manual versus ChatGPT feedback in collaborative programming, reporting that AI-supported feedback accelerated task completion and coding accuracy, though instructor guidance remained essential for conceptual understanding. Advancing assessment approaches, Ba *et al.* (2025) applied network analytics to generative AI-assisted feedback in inquiry-based discussions, revealing improvements in participation equity and depth of argumentation. Complementing these findings, de Barba, Oliveira, and English (2025) developed and validated a learning analytics rubric for self-regulated learning, highlighting how AI-driven feedback can be systematically measured and aligned with learner autonomy. Collectively, these studies underscore the pedagogical promise and nuanced implementation requirements of AI in higher education.

d) Topic 4: Language learning & instructional design

Emerging studies on this topic demonstrate the transformative role of AI in language learning, emphasizing pedagogical effectiveness, learner engagement, and teacher facilitation. Arani (2025) investigated AI-mediated problem-based language learning, demonstrating that AI tools can reduce teacher workload while empowering students to engage in autonomous problem-solving and collaborative tasks. Lin, Lin, and Tang (2025) examined AI-supported pre-reading scaffolding in English reading comprehension, reporting improvements in learning motivation, positive reading attitudes, and comprehension outcomes. Liu and Xiao (2025) conducted a qualitative study of Chinese university teachers' engagement with generative AI across the ADDIE instructional design stages, revealing varied adoption patterns influenced by teaching experience, perceived usefulness, and institutional support. Li *et al.* (2025) explored peer learning in AI-assisted speech writing, finding that collaborative engagement enhanced prompt literacy, writing quality, and critical thinking disposition. Complementing these studies, Yang, Wu, and Deris (2025) investigated EFL learners' emotional and psychological responses in AI-assisted language instruction, showing that teacher support mitigates technostress and promotes positive emotions and well-being.

e) Topic 5: Digital education, research & student factors

Recent literature underscores the growing influence of artificial intelligence (AI) on educational practices, learner engagement, and digital literacy. Low, Wut, and Pok (2025) conducted a comparative study in higher education institutions, highlighting how AI facilitators can enhance student-centered learning experiences, though effectiveness varies with institutional support and cultural context. Zhou, Ren, and Lang (2025) examined AI-based adaptive learning technologies, finding significant improvements in student motivation, engagement, and personalized learning pathways. Luo *et al.* (2025) investigated AI information literacy among high school students through a social-ecological lens, identifying cognitive, social, and environmental factors that influence students' competence and readiness to interact with AI systems. Waqas, Hania, and Xu (2025) explored the phenomenon of AI-enabled academic dishonesty, revealing that general attitudes toward AI and moral disengagement play critical roles in predicting AI-based plagiarism in higher education.

f) Topic 6: Learning systems in Asian contexts

Recent findings indicate the growing role of artificial intelligence (AI) in education, with a notable emphasis on Asian contexts and pedagogical applications. Pham, Nguyen, Ha, and Ngoc (2023) examined AI-assisted learning in engineering education, demonstrating that digital transformation can enhance student engagement, practical skills, and adaptive learning opportunities. In language education, Wu and Li (2024) conducted a meta-analysis on AI chatbots for EFL learners in Asia, revealing positive effects on listening, speaking, and overall language proficiency, while emphasizing the importance of context-sensitive implementation. Jia *et al.* (2024) compared generative AI– and

teacher-generated problem-solving tips in mathematics, reporting that AI provided efficiency and consistency benefits, though human guidance remained essential for conceptual understanding. Li *et al.* (2025a) proposed an AI-supported framework to analyze classroom dialogue in Asian classrooms, showing improvements in in-class interaction quality and teacher reflection. Expanding to curriculum and assessment, Abbasi, Wu, and Luo (2025) explored AI's impact on global higher education curricula.

g) Topic 7: Academic performance & course feedback

Contemporary studies document the role of AI in enhancing academic performance and providing course feedback across higher education contexts. Wang (2024) examined EFL students' self-regulated use of machine translation and generative AI tools in academic writing, showing that students' learning outcomes improved when AI systems were used strategically, though sociocultural factors influenced effective adoption. Aaron *et al.* (2025) investigated human-AI interaction to optimize teaching workload and support student writing, reporting that AI-assisted feedback systems increased efficiency, personalized guidance, and overall student performance. Aljasser (2025) compared instructor- and ChatGPT-generated feedback in academic writing, finding that while AI feedback was valued for immediacy and clarity, students still relied on human feedback for nuanced understanding, indicating the importance of blended feedback models. Beardsley *et al.* (2025) piloted a learning agreement framework for generative AI use in university courses, emphasizing structured policies to ensure feedback quality and academic integrity. Castellanos-Reyes and Leppard (2025) explored online project-based learning in data science, using Sankey visualization to track course engagement and student decision-making, demonstrating that AI-supported systems can enhance learning, guide course selection, and improve academic outcomes.

h) Topic 8: Collaborative learning & knowledge building approaches

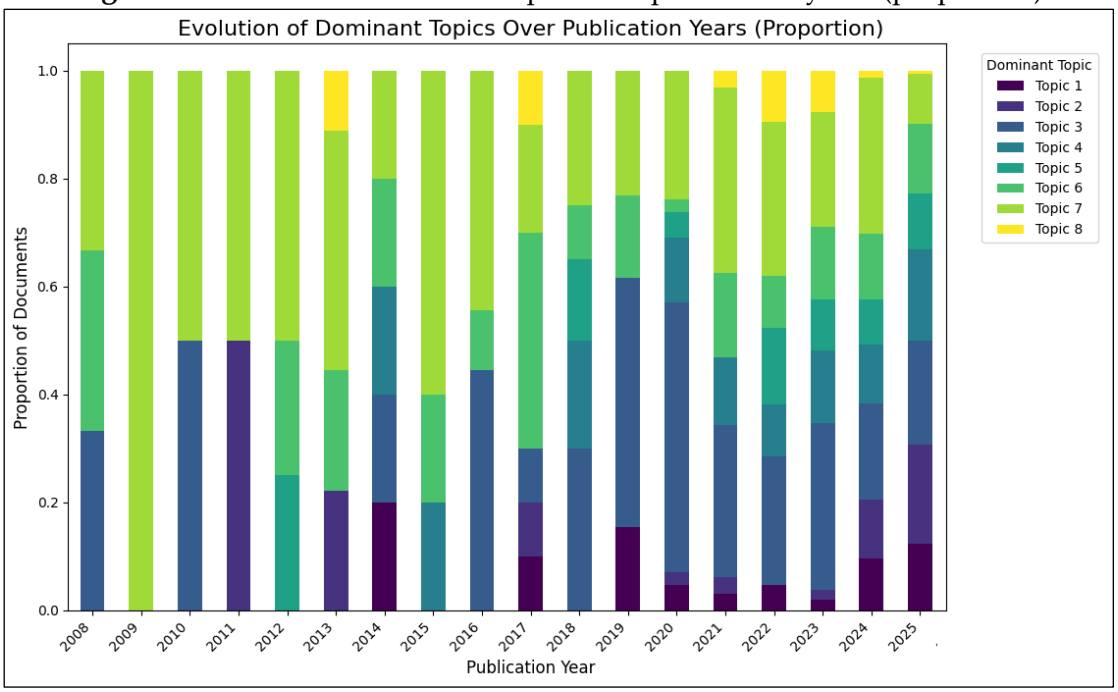
Current research reveals the integration of AI to enhance collaborative learning and knowledge-building approaches in educational settings. An *et al.* (2025) examined generative AI in mind mapping-based collaborative environments, showing that AI support improved student teachers' task performance and facilitated more effective group knowledge construction. Hong *et al.* (2025) explored AI-supported idea-developing discourse within teacher communities for STEAM lesson design, demonstrating that collaborative knowledge-building environments fostered professional agency and sustained group regulation. Liu (2025) proposed a human–machine collaborative framework for learning Japanese sentence patterns, emphasizing AI-driven knowledge discovery to support iterative learning and group problem-solving. Sigalov and Cohen (2025) leveraged Wikipedia in higher education courses, creating an online collaborative learning model that enhanced students' competencies while promoting structured knowledge creation. Collectively, these studies indicate that AI-integrated approaches can strengthen collaborative learning, regulate group

interaction, and support knowledge-building processes, highlighting the potential of human–AI collaboration to advance both performance and collective understanding.

3.2.2 Evolution of topics

As shown in Fig. 9, the eight topics provide a refined and highly interpretable thematic structure for the dataset, potentially offering clearer distinctions between specific research areas in AIHEd from 2008 to 2025.

Figure 9: Evolution of dominant topics over publication years (proportion)



Note: For clarity, topics are labeled 1–8, corresponding to the original LDA topics 0–7 from Python's Gensim output.

In Figure 9, the stacked bar chart shows how the prevalence of each theme changes over time. Topic 1 (Learning environment & educational technology) appears to have a fluctuating presence, with some years showing higher proportions. Topic 2 (LLM & medical education) shows a notable increase in recent years, especially from 2023 onwards, indicating a growing interest in large language models within medical education. Topic 3 (Learning analytics, higher education & teaching with ChatGPT) also demonstrates a rising trend in recent years, aligning with the increased adoption and discussion of AI tools like ChatGPT in higher education. Topic 4 (Language learning & instructional design) maintains a relatively stable, though generally smaller, proportion across most years. Topic 5 (Digital education, research & student factors) shows a consistent presence. Topic 6 (Learning systems in Asian contexts) shows a slowing increasing tendency. Topic 7 (Academic performance & course feedback) appears to be a foundational and consistent topic throughout the years. Topic 8 (Collaborative learning & knowledge building approaches) shows varied proportions, with less focus in recent years.

3.3 Conceptual Structure and Emerging Research Priorities (RQ3)

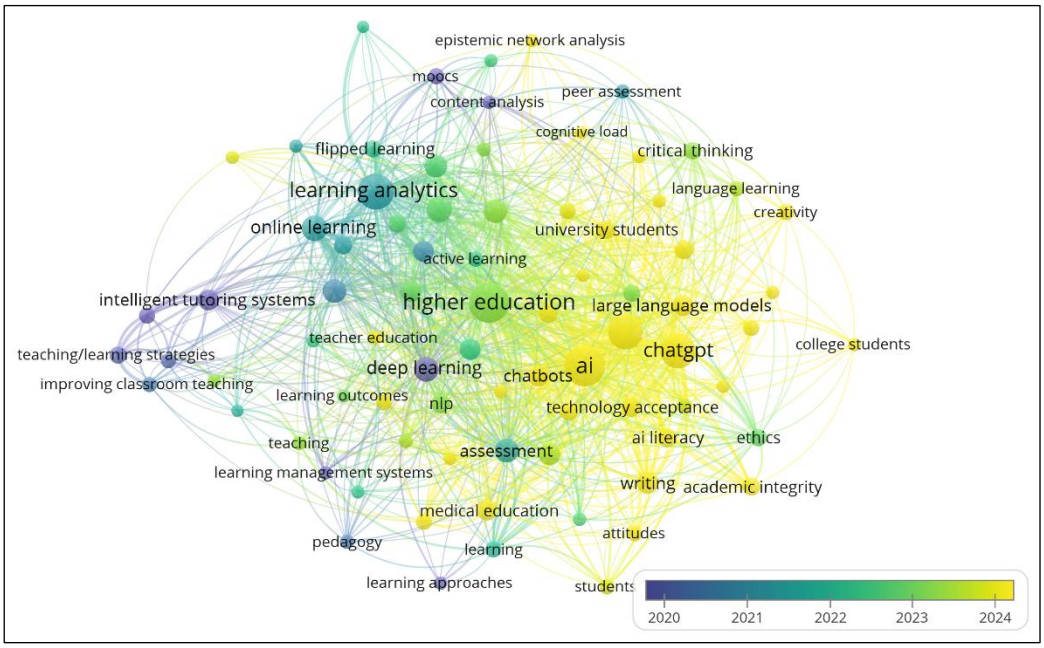


Figure 10: Co-occurrence network of keywords (2008-2025)

With VOSviewer, we retrieved the keywords in 2024 and 2025 (academic integrity, AI, AI chatbots, AI in education, AI literacy, attitudes, ChatGPT, college students, creativity, EFL, ethics, generative AI, motivation, scale development, self-determination theory, self-efficacy, technology acceptance, writing). As shown in Fig. 10, publications in 2024 and 2025 reflect a rapid expansion of AI in education, with research focusing on both technological capabilities and learner-centered applications. Ethical and policy concerns, including academic integrity, fairness, and responsible use of generative AI and ChatGPT, remain central. Studies on AI literacy and technology acceptance will be crucial for understanding adoption and trust in AI-mediated learning.

Psychological and motivational factors, such as self-efficacy, motivation, attitudes, and self-determination, are increasingly examined to understand learner engagement. Pedagogical integration of AI tools, including chatbots, large language models, and AI-supported writing, enhances instruction, feedback, and creativity.

Domain-specific applications, particularly EFL learning, writing, and creativity, are emerging, alongside methodological advances in validated scales for AI literacy, attitudes, and technology acceptance. Future research will likely prioritize ethical, learner-centered, and pedagogically grounded approaches, exploring AI integration, learner–AI interactions, reliable assessment, longitudinal effects, and contextual variations in adoption.

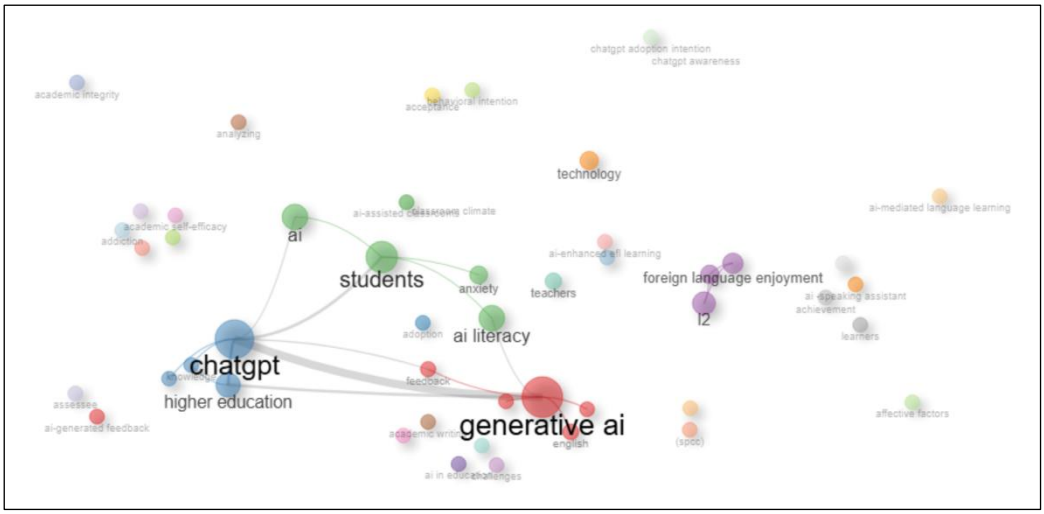


Figure 11: Co-occurrence network of the 26 hot papers

To better predict future research trends, we further analyze with VOSviewer the Co-occurrence network of the 26 hot papers listed in WoS. The co-occurrence network of keywords in AI-enhanced higher education research reveals a multi-layered structure, comprising several connected thematic clusters alongside numerous unconnected or peripheral topics. Cluster 1, including generative AI, feedback, self-regulated learning, English, and model, represents a methodological and tool-focused hub, with generative AI serving as the main connector (betweenness = 34.477, PageRank = 0.132). These keywords reflect research emphasizing the design, evaluation, and theoretical modeling of AI applications in educational contexts. Cluster 2, composed of ChatGPT, higher education, knowledge, and learning analytics, forms the central technological hub, with ChatGPT acting as the dominant connector (betweenness = 35.043, PageRank = 0.132). This indicates that ChatGPT is not only a focal point for AI research but also a bridge linking pedagogical practices with data-driven learning analytics. Cluster 3 focuses on student-centered outcomes, including students, AI literacy, and anxiety, with students as the primary connector (betweenness = 13.023, PageRank = 0.07), highlighting learner-focused considerations such as competence, engagement, and emotional response to AI tools. Cluster 4, comprising foreign language enjoyment, L2, and willingness to communicate, forms a self-contained niche, with zero betweenness and high closeness (0.5), indicating strong internal cohesion but minimal integration with AI-focused clusters.

Beyond these four clusters, a large number of keywords (Clusters 5–38) remain unconnected, with PageRank values near 0.007, representing emerging topics, highly specialized areas, or novel research directions not yet integrated into the broader network. These include concepts such as AI-assisted classrooms, academic self-efficacy, ChatGPT adoption intention, and avatar, suggesting a rich set of potential avenues for future exploration. However, the isolation of some clusters, particularly Cluster 4 and unconnected nodes, highlights opportunities for interdisciplinary research, for example,

integrating AI tools like ChatGPT into foreign language learning, classroom climate, and academic skill development.

4. Conclusion

This study provides a comprehensive mapping of AIHEd from 2008 to 2025, integrating bibliometric, STM, and network analyses. The Bibliometrix analysis revealed a clear trajectory of growth: research output was modest before 2015, increased steadily from 2016 to 2022, and surged sharply between 2023 and 2025, peaking at 1,078 publications. This pattern reflects the accelerating global interest in AI applications, particularly generative AI and large language models, in higher education. Publications are concentrated in journals such as Education and Information Technologies, BMC Medical Education, and Interactive Learning Environments, while leading authors and institutions, including Monash University, the University of Hong Kong, and the Education University of Hong Kong, act as central hubs of research and collaboration, emphasizing the value of cross-institutional and cross-country partnerships in advancing AIHEd scholarship. Country-level analysis shows China producing the largest aggregate output, whereas the US and UK exhibit higher per-article impact. Furthermore, most of the highly cited AIHEd articles were published in 2023 and 2024, clustering around three key themes: generative AI in education, learning analytics, and broader educational technology research. Keyword analysis in RStudio, using packages such as dplyr, tidyr, stringr, and ggplot2, shows a clear evolution of research focus: from foundational AI and educational technology (2008–2013), to data-driven pedagogy and personalized learning (2014–2019), and finally to the generative AI era (2020–2025).

The STM analysis identified eight coherent topics, capturing the evolving thematic structure of AIHEd research. These topics reflect both the technical development of AI tools and their pedagogical applications, providing a nuanced understanding of how research has shifted from foundational AI studies toward practical, learner-centered applications. Temporal keyword analyses further demonstrate a progression from early AI development and educational analytics toward current themes in generative AI, ChatGPT adoption, ethical considerations, and AI-mediated pedagogy.

VOSviewer-based co-occurrence network analyses revealed four main clusters encompassing technological innovation, pedagogical integration, ethical and policy considerations, and AI literacy and adoption. These clusters illustrate that while AI's technical capabilities drive research, ethical issues, including fairness, academic integrity, and responsible use of generative AI, remain central.

These findings demonstrate that AIHEd research is rapidly expanding, internationally collaborative, and thematically diverse. The study offers actionable insights for educators, institutions, and policymakers: guiding curriculum design that integrates AI tools, prioritizing research funding toward emerging themes, and developing frameworks for responsible and equitable adoption of AI in higher education. It has to be admitted that this study has several limitations. First, it focused on English-

language articles indexed in the Web of Science Core Collection under Educational Research, excluding other databases, practical reports, or industry analyses. Second, the time frame was limited to 2008–2025, potentially omitting earlier foundational studies or emerging publications. Third, the analysis mainly relied on bibliometrix (R), standalone VOSviewer, and STM. While these tools provide robust insights into trends, thematic clusters, and collaboration networks, alternative methods might capture additional nuances. Despite these limitations, the study provides a comprehensive overview of AIHEd.

Future studies could systematically investigate how to bridge the gaps between AI-enhanced pedagogical methods and learner-centered outcomes. For instance, research could examine AI-assisted classrooms and AI-mediated language learning in connection with ChatGPT and generative AI to understand how these tools affect student engagement, self-regulated learning, and academic self-efficacy. Similarly, studies could explore the integration of AI-generated feedback with academic writing, AI-assisted writing, and classroom assessment practices, evaluating their influence on academic achievement, stress, and behavioral intention. Investigating AI adoption patterns, including ChatGPT adoption intention, acceptance, and attitudes toward AI, could clarify barriers and facilitators to effective AI use in higher education. Moreover, research could address affective factors, anxiety, and foreign language enjoyment, examining how AI tools enhance motivation, willingness to communicate, and learner satisfaction in L2 contexts. Taken together, these directions would foster a more cohesive understanding of AI's pedagogical, cognitive, and affective impacts in higher education.

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Conflict of Interest Statement
We hereby declare that we, the authors of this paper, have no conflict of interest that influenced our sense of judgement or analysis in this academic paper.

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