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Artificial Intelligence for Digital Literacy in Higher Education: A Systematic Literature Network Analysis and Bibliometric Analysis

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Abstract: This study aims to map the intellectual structure, research trends, and future directions of Artificial Intelligence (AI) for Digital Literacy in Higher Education using a Systematic Literature Network Analysis (SLNA) approach. Data were collected from the Scopus database following the PRISMA 2020 protocol, resulting in 242 journal articles published between 2019 and 2025. Bibliometric mapping was conducted using VOSviewer, while Latent Dirichlet Allocation (LDA) topic modelling was applied to identify thematic patterns and emerging research themes. The findings reveal a substantial increase in publications after 2023, coinciding with the rapid growth of generative AI technologies. Six major thematic clusters were identified, covering AI-based digital literacy, academic integrity and ethics, human-centered factors, pedagogical adoption, digital competence, and AI-supported learning technologies. Topic modelling further revealed ten dominant research themes, with generative AI



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emerging as the most influential topic in recent years. The study highlights a shift from technology-oriented perspectives toward more pedagogical, ethical, and human-centered approaches. By integrating SLNA, bibliometric network analysis, and LDA topic modelling, this research provides a comprehensive overview of the evolving research landscape and offers strategic directions for future research and policy development in higher education.

Keywords: Artificial intelligence; digital literacy; higher education; bibliometric analysis; systematic literature network analysis; topic modelling.

高等教育数字素养的人工智能：系统性文献网络与文献计量分析

摘要：本研究旨在通过系统文献网络分析（SLNA）方法，绘制人工智能（AI）在高等教育数字素养领域的智识结构、研究趋势及未来发展方向。数据从Scopus数据库收集，遵循PRISMA2020协议，2019年至2025年间发表了242篇期刊文章。使用VOSviewer进行文献计量映射，同时应用潜在狄利克雷分配（LDA）主题建模以识别主题模式和新兴研究主题。研究结果显示，2023年后发表的论文数量大幅增加，这与生成式人工智能技术的快速发展相吻合。确定了六个主要主题集群，涵盖基于人工智能的数字素养、学术诚信与伦理、以人为本的因素、教学采纳、数字能力以及人工智能支持的学习技术。主题建模进一步揭示了十个主导研究主题，其中生成式人工智能成为近年来最具影响力的主题。该研究强调了从技术导向的转变，转向更具教学性、伦理性和以人为中心的方法。通过整合SLNA、文献计量网络分析和LDA主题建模，本研究全面概述了不断演变的研究格局，并为高等教育未来的研究和政策制定指明了战略方向

关键词：人工智能;数字素养;高等教育;文献计量分析;系统文献网络分析;主题建模。

1. Introduction

The rapid development of Artificial Intelligence (AI) technology has brought significant transformation in higher education, especially in strengthening digital literacy as a key competency in the digital era. The integration of AI in Education not only improves students' technical abilities, but also contributes to the development of critical thinking skills, problem-solving and readiness to face the technology-based world of work [1], [2], [3]. Various AI-based technologies, such as intelligent tutoring systems, adaptive learning platforms and generative AI have encouraged the creation of more personalized and adaptive learning experiences, thereby increasing student engagement and learning outcomes [4], [5], [6]. However, the implementation of AI also presents various challenges including ethical issues, data privacy, and technology access gaps that require a comprehensive approach in managing it [5], [6].

On the other hand, digital literacy in higher education is a multidimensional concept that continues to develop along with the advancement of AI technology. This transformation includes changes in the way students access information, develop media literacy, and interact in a digital learning environment [7], [8], [9]. Therefore, an analytical approach is

needed that is able to map research trends, management structures, and the development of the main themes in this field. The Systematic Literature Network Analysis (SLNA) approach is relevant because it is able to integrate systematic literature review with bibliometric network analysis to identify research clusters, influential authors, and themes that develop [10], [11]. In addition, SLNA also allows for adaptive and participatory updates of the digital literacy framework in response to the dynamics of AI development [8], [12].

SLNA has a strategic role in supporting *evidence-based policy* decision making and the development of relevant curriculum. By citing empirical findings related to the application of AI in learning, SLNA can provide insights into how the technology improves digital literacy, including in aspects of learning personalization, strengthening critical thinking and ethical reasoning [13], [14]. In addition, this approach can also identify obstacles to implementation, such as lecturer readiness and infrastructure limitations so that it can lay the foundation for designing a more effective and inclusive institutional strategy [6], [13].

From a methodological perspective, SLNA offers an advantage in revealing the relationships between concepts and research gaps through network analysis

such as co-citation and keyword co-occurrence, which often cannot be identified through a review of the traditional literature [10], [15]. This approach is especially important for interdisciplinary topics such as AI and digital literacy, which involve complex interactions between technology, pedagogy and Education policy.

In addition, the need for a comprehensive study is increasingly urgent in line with the acceleration of digital transformation in higher education, especially after the covid 19 pandemic which accelerates the adoption of digital technology and at the same time shows the digital literacy gap in various regions [1], [16]. In this context, SLNA can provide a broader understanding of global trends and regional contexts, thereby supporting the development of more inclusive and sustainable Education practices.

Based on this description, the implementation of systematic literature network analysis (SLNA) on the topic of Artificial Intelligence for digital literacy in higher education is very important to identify research trends, reveal knowledge gaps and formulate future research and policy directions. This approach is expected to be able to make a significant contribution in integrating AI technology effectively, ethically and sustainably in higher education.

Although previous research has examined Artificial Intelligence in Education, digital literacy, and educational technology through bibliometric and review approaches, most have focused on these domains separately. Existing studies primarily investigate the adoption of AI in education, digital competency development, or educational technology trends without comprehensively exploring the intersection between Artificial Intelligence and Digital Literacy in Higher Education.

Therefore, this study addresses this gap by integrating Systematic Literature Network Analysis (SLNA), PRISMA-based systematic filtering, bibliometric network analysis using VOSviewer, and latent Dirichlet Allocation (LDA) topic modeling in one analytical framework. Unlike previous bibliometric studies, this approach allows not only the identification of publication trends, collaboration networks, and keyword relationships but also the exploration of latent thematic structures and emerging research directions. As a result, this research provides a more comprehensive understanding of how Artificial Intelligence shapes the development of digital literacy in higher education and offers strategic insights for future research and policy development.

2. Literature Review

2.1. Artificial Intelligence In Higher Education

Artificial Intelligence (AI) is increasingly transforming higher education by enhancing teaching, learning, administrative efficiency, and research

processes. In teaching and learning, AI enables personalized and adaptive learning environments through intelligent tutoring systems, automated assessment, and real-time feedback, while generative AI tools such as ChatGPT foster interactive learning, critical thinking, and creativity [17], [18]. From an institutional perspective, AI improves operational efficiency by automating administrative tasks and utilizing predictive analytics to support student retention and decision-making [19]. Moreover, AI contributes to research advancement by facilitating large-scale data analysis and interdisciplinary collaboration [20]. Despite these benefits, significant challenges remain, including ethical concerns related to data privacy, algorithmic bias, and academic integrity, as well as issues of faculty readiness, unequal access, and the lack of comprehensive regulatory frameworks [21], [22]. Therefore, future development requires balanced integration that combines technological innovation with human-centered pedagogy, supported by ethical guidelines, inclusive infrastructure, and continuous professional development. Overall, AI represents a transformative force in higher education, but its sustainable and responsible implementation depends on addressing these critical challenges [23].

2.2. Artificial Intelligence in Digital Literacy Development

Artificial Intelligence (AI) plays a transformative role in digital literacy development by enhancing individuals' ability to access, evaluate, and apply digital information critically and effectively. AI-powered tools support the development of key digital literacy skills such as information verification, bias detection, and ethical technology use, while generative AI applications further promote active engagement and advanced information processing [8]. In addition, AI enables personalized learning and adaptive feedback, allowing learners to develop digital competencies according to their needs and learning pace [2]. The integration of AI into educational curricula also strengthens critical thinking, problem-solving, and creative skills, positioning digital literacy as a core competency in AI-driven environments [24]. However, challenges such as ethical concerns, algorithmic bias, unequal access, and varying levels of digital readiness remain significant barriers to effective implementation [25]. Therefore, the successful development of AI-driven digital literacy requires inclusive strategies, teacher training, and ethical frameworks to ensure equitable and responsible use of technology, ultimately supporting sustainable and human-centered digital competence development [26].

3. Method

This study integrates Systematic Literature Network Analysis (SLNA) and content analysis as an integrated

methodological approach to compile a comprehensive review of the application of deep learning in strengthening digital literacy. This hybrid approach provides a more substantial analytical advantage, both in terms of breadth of scope and depth of interpretation, compared to the use of systematic literature review (SLR) or bibliometric analysis (BA) separately [27]. In particular, SLNA is used to explore the evolution of the research landscape, identify key thematic structures, and uncover conceptual gaps that have the potential to be the direction of further research [28]. Meanwhile, content analysis plays a role in deepening the interpretation of the dynamics of emerging global

themes as well as synthesizing the latest empirical findings relevant to the context of the study [29].

This research began with a data collection process that referred to the PRISMA 2020 protocol, then continued with bibliometric network analysis using VOSviewer [30], then for the process of mapping and grouping qualitative content using the Orange Data Mining application [31]. The series of flow of this research methodology is presented in figure 1, which describes the main stages of SLNA and the content analysis implemented in this study.

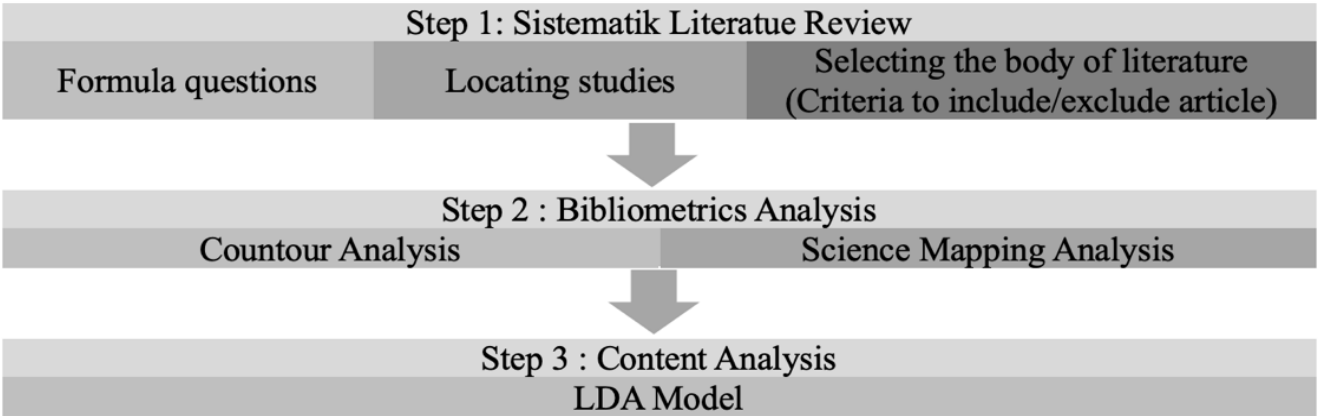


Figure 1. Steps in Systematic Literature Network Analysis

The initial stage of this research looks at the implementation of PRISMA 2020, which is a standard framework in the implementation of systematic reviews [32]. The search process is carried out through the Scopus database which was chosen because of its wide scope and high credibility [33]. Scopus was chosen as the primary source by contributing its capacity in indexing highly reputable scientific publications covering the fields of artificial intelligence, digital literacy, and higher education. These characteristics make Scopus a relevant database to support the study of Artificial Intelligence integration in the development of digital literacy in the higher education environment. In addition, the availability of comprehensive and standardized metadata allows for an optimal level of compatibility with a wide range of bibliomatrix analysis tools, while ensuring the validity and consistency of data in the citation mapping process. Inclusion and exclusion criteria are established prior to the screening process to ensure methodological consistency and relevance to the research objectives. Only studies that met all inclusion criteria were retained for further analysis. The search process uses the following keyword combinations:
("artificial intelligence" OR AI OR "machine learning" OR "generative AI") AND ("digital literacy" OR "digital competence" OR "digital skills" OR

"information literacy") AND ("higher education" OR university OR college OR "tertiary education").

The Scopus search was carried out on April 10, 2026. Scopus was chosen as the primary data source due to its wide coverage of peer-reviewed scientific publications and its compatibility with bibliometric analysis software. The search was limited to journal articles published between 2019 and 2025 and written in English. Conference proceedings, book chapters, review papers, editorials, notes, and publications written in languages other than English are excluded to ensure consistency and quality of the data set.

Duplicate records are checked during the screening process using Scopus metadata fields, including title, DOI, author name, and year of publication. No duplicate records were identified in the final dataset, indicating that all of the records stored represent unique publications.

To ensure methodological accuracy and minimize potential selection bias, the title and abstract screening process is carried out independently by Authors 1 and 4 who are responsible for data curation and initial screening of the literature. Furthermore, the full-text feasibility assessment was independently validated by Authors 2 and 3 as part of the methodological evaluation process. Author 5 contributes to data management, bibliometric visualization, and technical

verification of the analysis conducted, while Author 6 contributes to conceptual development, interpretation of findings, manuscript review, and overall quality assurance. The implementation of this phased screening

and validation procedure aims to ensure a high level of reliability between assessors and methodological consistency, resulting in a final data set that meets all inclusion criteria for analysis at the next stage of research.

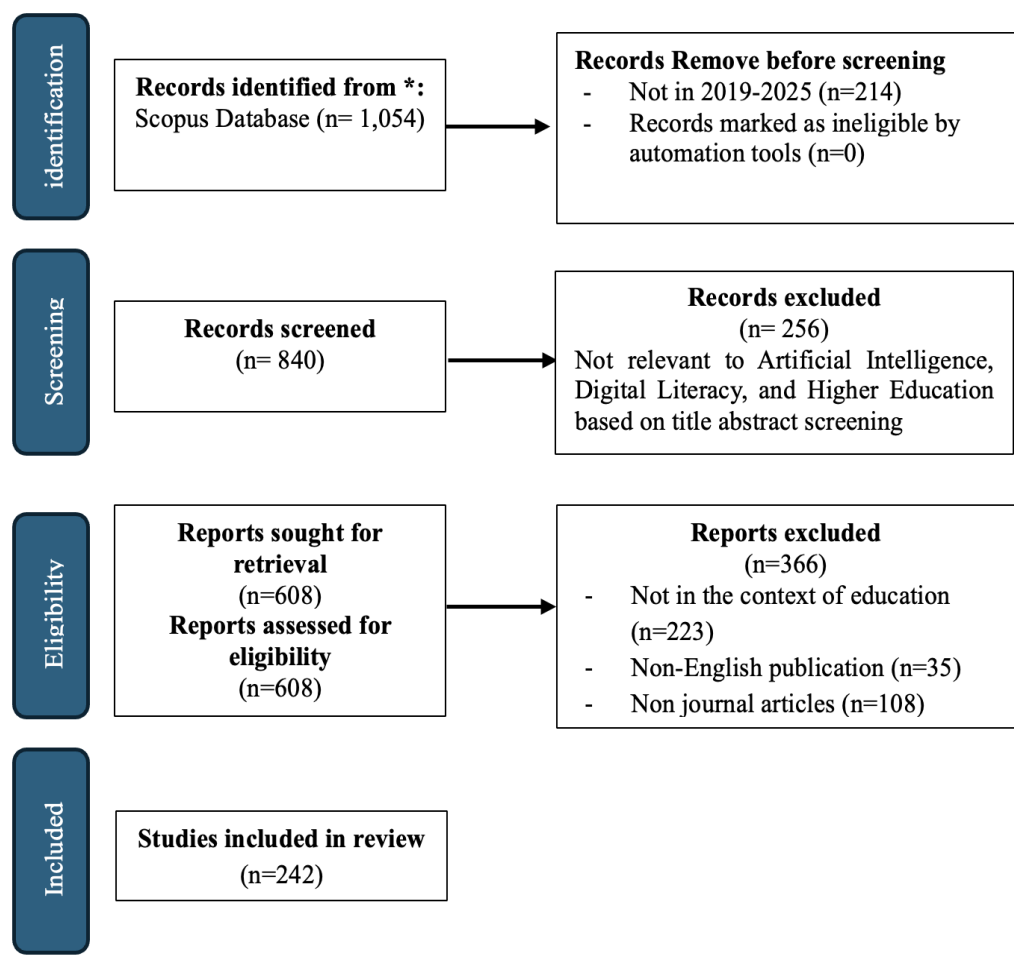


Figure 2. A PRISMA flowchart outlining the systematic literature search and selection process for *Artificial Intelligence for Digital Literacy in Higher Education*

Figure 2 illustrates the PRISMA 2020 screening process used in this study. An initial search identified 1,054 records from the Scopus database. After deleting 214 records published outside of the selected period (2019–2025), 840 records remain for title and abstract playback. Furthermore, 256 records were excluded because they were irrelevant to the intersection of Artificial Intelligence, Digital Literacy, and Higher Education. The remaining 608 records underwent a full-text feasibility assessment, resulting in the exclusion of 366 records due to educational context mismatches (n = 223), non-English language (n = 35), and non-article document types (n = 108). As a result, the final dataset of 242 journal articles was included in a systematic literature network analysis and bibliometric review.

After the filtering process, the datasets are exported in .ris format and processed in two main stages: Systematic Literature Network Analysis (SLNA): Bibliometric mapping is performed using VOSviewer version 1.6.20. The co-occurrence analysis was carried out based on the author's keywords using the full calculation method. A minimum keyword occurrence threshold of five is applied to reduce noise and improve visualization clarity. Of the initial set of 982 keywords extracted, 38 keywords met the threshold and were included in the final network analysis. Network visualization, overlay visualization, and collaboration mapping are generated to identify thematic structures and research trends.

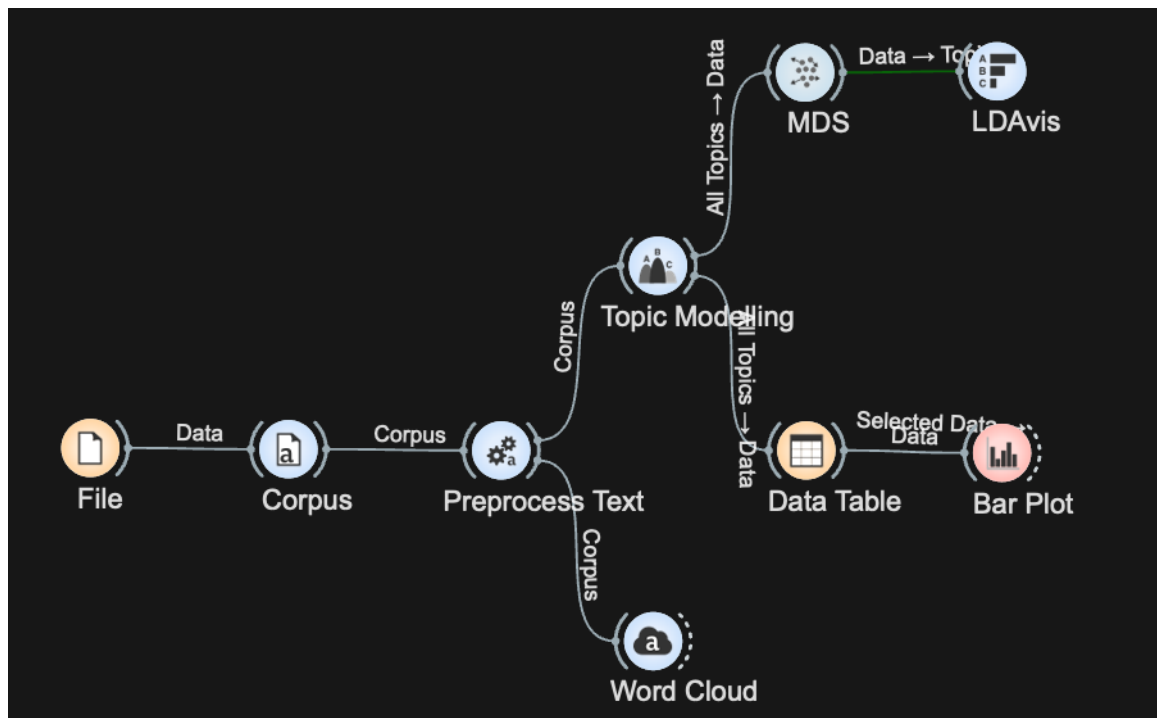


Figure 3. Topic Modeling Through The Corpus Title and Abstract

Topic modeling was carried out using the Latent Dirichlet Allocation (LDA) algorithm applied in Orange Data Mining. Prior to modeling, the corpus of text consisting of article titles and abstracts underwent several stages of preprocessing, including lowercase conversion, punctuation removal, word stop removal, tokenization, WordNet lemmatization, and bigram creation to retain meaningful terms such as "Artificial Intelligence". The optimal number of topics is determined through the evaluation of the coherence score (Cv) and the model's interpretability. Based on these criteria, ten topics ($k = 10$) were selected for the final model. Topic labels are assigned manually by checking for the most representative keywords and reviewing the thematic content of the related documents.

4. Result and Discussion

4.1. Publication Trends

This section presents a quantitative and qualitative assessment of the research landscape based on metadata obtained from the scopus database. A total of 242 articles that have met the criteria and examined the intersection between *Artificial Intelligence for Digital Literacy in Higher Education* show a significant growth pattern in recent years. In 2019 there were no publications in the form of journal articles, where the

scientific output in that period was dominated by books and conference proceedings. Entering 2020, the publication of articles began to appear with a very limited number of 1 document. This trend then showed a gradual increase in 2021 and 2022 with 4 publications each. More significant growth began to be seen in 2023 with 14 publications, which then increased sharply, in 2024 to 45 publications. The most striking surge is in 2025, with a total of 174 documents published. This very rapid acceleration cannot be separated from the rapid development of artificial intelligence technology, especially the emergence of generative AI models such as ChatGPT which fundamentally changed the landscape of digital learning and pedagogical practices in higher education.

This phenomenon shows a paradigm shift from the use of artificial intelligence as a technical tool to its use as a core component in the digital learning ecosystem. In addition, the drastic increase post-2023 also reflects a global response to more critical digital literacy, including the ability to understand, evaluate and utilize AI technology ethically and reflectively. Overall, this trend confirms that the field of *artificial intelligence for digital literacy in higher education* has entered a phase of exponential growth, driven by the convergence between technological innovation, pedagogical needs and digital transformation in higher education globally.

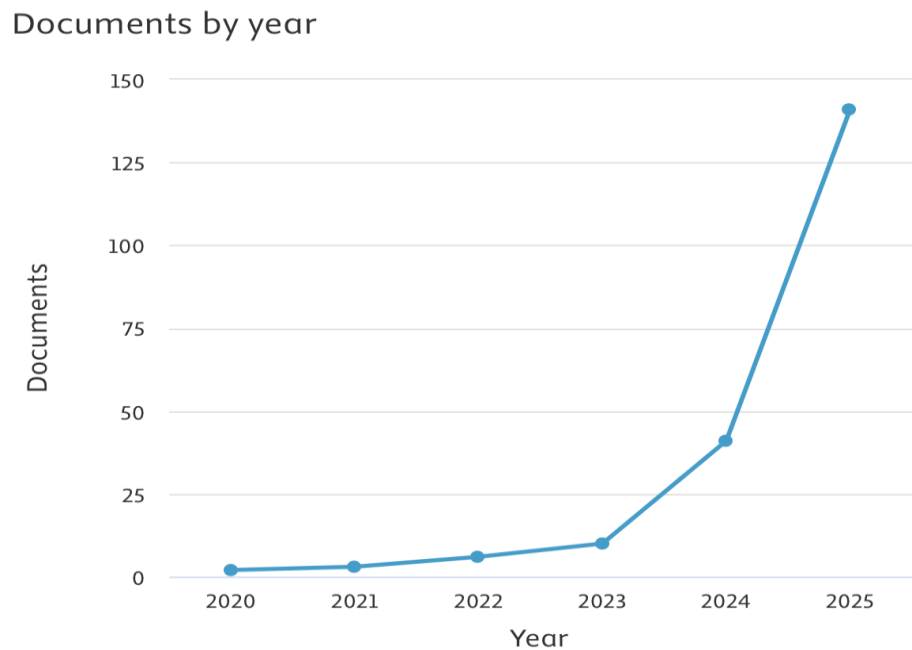


Figure 3. Number of Publications Each Year

4.2 Country Collaboration Analysis

Based on the analysis of 242 articles, the distribution of research contributions shows complex dynamics between productivity and scientific impact. The United States 27 documents, Spain 23 documents and 22 documents emerged as the most productive contributors. Other countries such as the United Kingdom, Indonesia and Malaysia also showed significant contributions with around 10 to 11 publications each.

However, the volume of publications does not always match the impact of the citations in this dataset. In terms of citations, Hong Kong recorded 666 citations from just five documents, resulting in the highest Citation per Document (CPD) score of 133.20.

These findings suggest that citation visibility can be influenced by factors beyond publication volume, including journal exposure, collaborative networks, and the relevance of specific research topics. A similar pattern was observed in Turkey (CPD = 43.60) and Romania (CPD = 39.29), where a small number of publications resulted in substantial citation impact. In contrast, countries such as Thailand (CPD = 0.25), Nigeria (CPD = 0.83), and Mexico (CPD = 1.00) showed lower citation impact in the data set. These findings should be interpreted with caution, as citation-based indicators reflect the visibility and influence of research in the corpus analyzed rather than the overall quality of the research.

Table 1. Country Productivity and Citation Impact

Country	Document	Citations	Total Link Strength	Citation Per Document (CPD)
Malaysia	10	70	12	7,00
China	22	300	10	13,64
Saudi Arabia	11	210	8	19,09
Pakistan	7	30	6	4,29
Australia	7	160	5	22,86
India	7	81	5	11,57
Spain	23	232	5	10,09
Thailand	8	2	5	0,25
United States	27	241	5	8,93
Oman	5	34	4	6,80
United Kingdom	11	68	4	6,18

Ecuador	6	13	3	2,17
Hongkong	5	666	3	133,20
Jordan	6	43	3	7,17
Mexico	5	5	3	1,00
Nigeria	6	5	3	0,83
Hungary	5	34	2	6,80
Indonesia	11	34	2	3,09
Peru	6	29	2	4,83
Poland	5	12	2	2,40
South Africa	6	45	2	7,50
Kazakhstan	6	31	1	5,17
Turkey	10	436	1	43,60
Germany	8	83	0	10,38
Romania	7	275	0	39,29

Total Link Strength (TLS) analysis provides an overview of the intensity of international collaboration between countries. The results showed that Malaysia (TLS=12) and China (TLS=10) had the highest level of collaboration, followed by Saudi Arabia (TLS=8) and

Pakistan (TLS=6). These findings suggest that these countries occupy relatively central positions within the international collaboration network represented in this dataset.

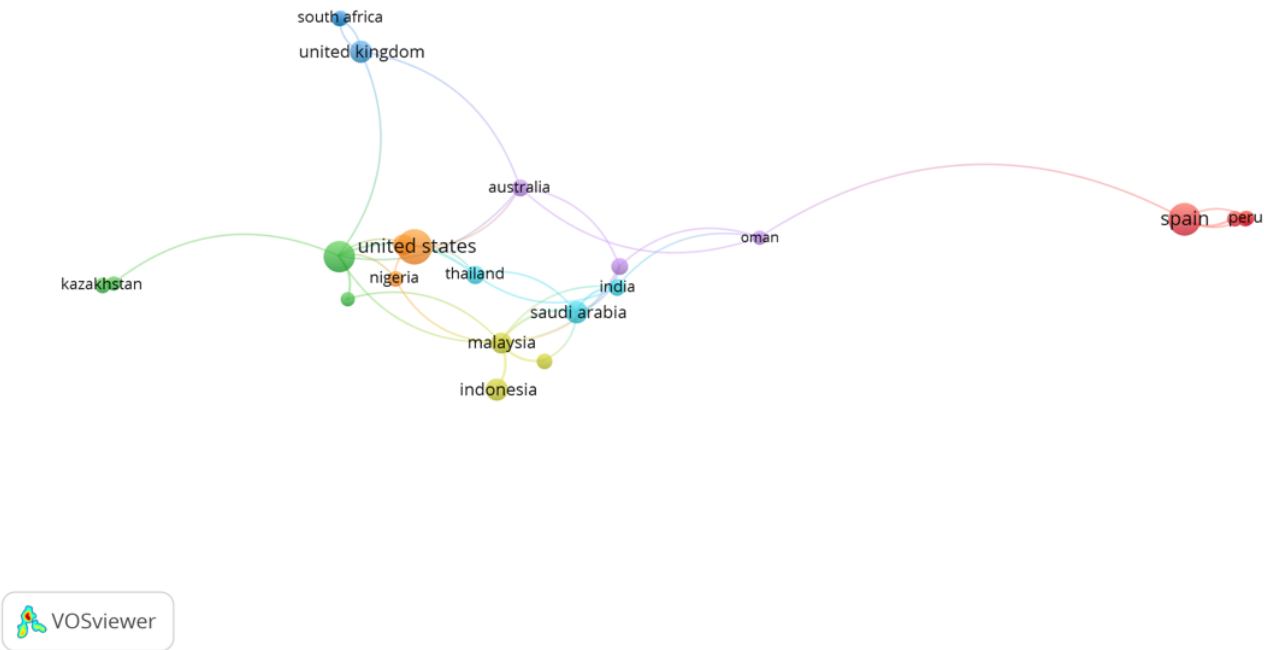


Figure 4. Co authorship Based on Affiliation Countries (Network Visualization)

The results of the country-based co-authorship analysis visualized through Vosviewer (Network Visualization) showed the formation of seven global collaboration clusters. Each cluster reflects a pattern of cooperation that tends to be regional, with several

countries acting as bridging nodes. The red clusters (Spain, Peru, Mexico and Ecuador) suggest relatively isolated regional collaboration, while the green clusters (China, Hong Kong, Kazakhstan, Poland) affirm Asia's strategic role as a center of global connectivity. The

dark blue (UK and South Africa) clusters reflect North-South collaboration, while the yellow (Indonesia, Malaysia, Jordan) and light blue (India, Saudi Arabia and Thailand) clusters reflect the consolidation of developing countries with limited connectivity. Meanwhile, the purple cluster (Australia, Oman and Pakistan) and the Orange cluster (United States, Turkey and Nigeria) show the role of developed countries as bridging nodes, with the United States and Australia serving as the main links in the global network.

Overall, these findings indicate a difference between publication volume and citation impact, where countries with a larger number of publications do not necessarily achieve higher citation visibility, while some countries with relatively limited output exhibit substantial citation impact. The results also suggest an uneven distribution of citation influence across countries within the analysed dataset. While developing countries such as Indonesia have demonstrated increasing research participation, their citation visibility remains comparatively lower than that of several established research hubs. These observations highlight the potential value of strengthening international collaboration, enhancing research dissemination strategies, and increasing participation in global scholarly networks.

4.3. Keyword Cluster Analysis

Based on the analysis of the co-occurrence of the keywords visualized in figure 6, this study identifies the intellectual pillar pillars during thematic transitions in the research landscape. To ensure a high signal-to-noise ratio, a minimum threshold of 5 keyword occurrences is applied. This threshold is strategically chosen to filter out terms that are idiosyncratic or peripheral in nature that do not contribute significantly to the source of the main thematic structure, thus ensuring clarity in the visualization of the data. From a total of 982 keywords that were initially extracted, the top 38 keywords were selected based on total link strength (TLS) to avoid excessive visual fragmentation. This selection allows for a more focused interpretation of the dominant concept that makes up the Artificial Intelligence for Digital Literacy in Higher Education study.

This analysis resulted in 6 main clusters that present a broad thematic structure in the research discourse that shows a multidimensional and integrated configuration of knowledge. The first cluster (green) dominated by "artificial intelligence" and "higher education", which serves as a connectivity hub with the highest level of

link strength, suggests its role as a central conceptual theme connecting multiple research domains. The second cluster (red), which includes "Academic Integrity", "AI ethics", "AI Literacy", as well as "ChatGPT" and "Generative AI", shows a shift in discourse towards normative implications and the impact of generative technology in educational practice. The third cluster (blue) highlights the human-centered dimension through student, human and perception which indicates an increased focus on user experience and interaction. The fourth cluster (yellow) integrates "teaching", "students" and "technology acceptance model", reflecting the importance of technology adoption and implementation in the context of learning. Meanwhile, the fifth cluster (purple) which contains "digital skills", "digital competence" and "large language models" emphasizes the urgency of human resource readiness, and the sixth cluster (light blue) which connects "educational technology" and "learning" presents the operational integration of AI in the education ecosystem.

4.4. Overlay Analysis

The overlay visualization complements the keyword co-occurrence analysis by illustrating the temporal evolution of research themes. This analysis enables the identification of emerging topics and shifts in research focus over time within the field of Artificial Intelligence for Digital Literacy in Higher Education. In addition, the overlay visualization shows the temporal dynamics in the development of the research which is reflected in the color gradation of blue to yellow in the time span of around 2024.0-2024.8. In the initial phase (2024.0-2024.2), keywords such as education, human and learning indicate a focus on the fundamental aspects of education and human interaction. Including the intermediate phase (2024.3-2024.5), there is artificial intelligence, higher education and digital literacy that reflects the conceptual consolidation and integration of AI in higher education. Meanwhile, in the latest phase (2024.6-2024.8), the emergence of ChatGPT, Generative AI, technology acceptance models and engineering education has led to a shift towards a more applicable and contextual approach, accompanied by increased attention to ethical issues such as AI ethics and academic integrity. Overall this pattern reflects a transition from a fundamental approach to a more complex integration, where technological innovation, pedagogical practices and ethical considerations are key elements in the evolution of higher education's digital literacy.

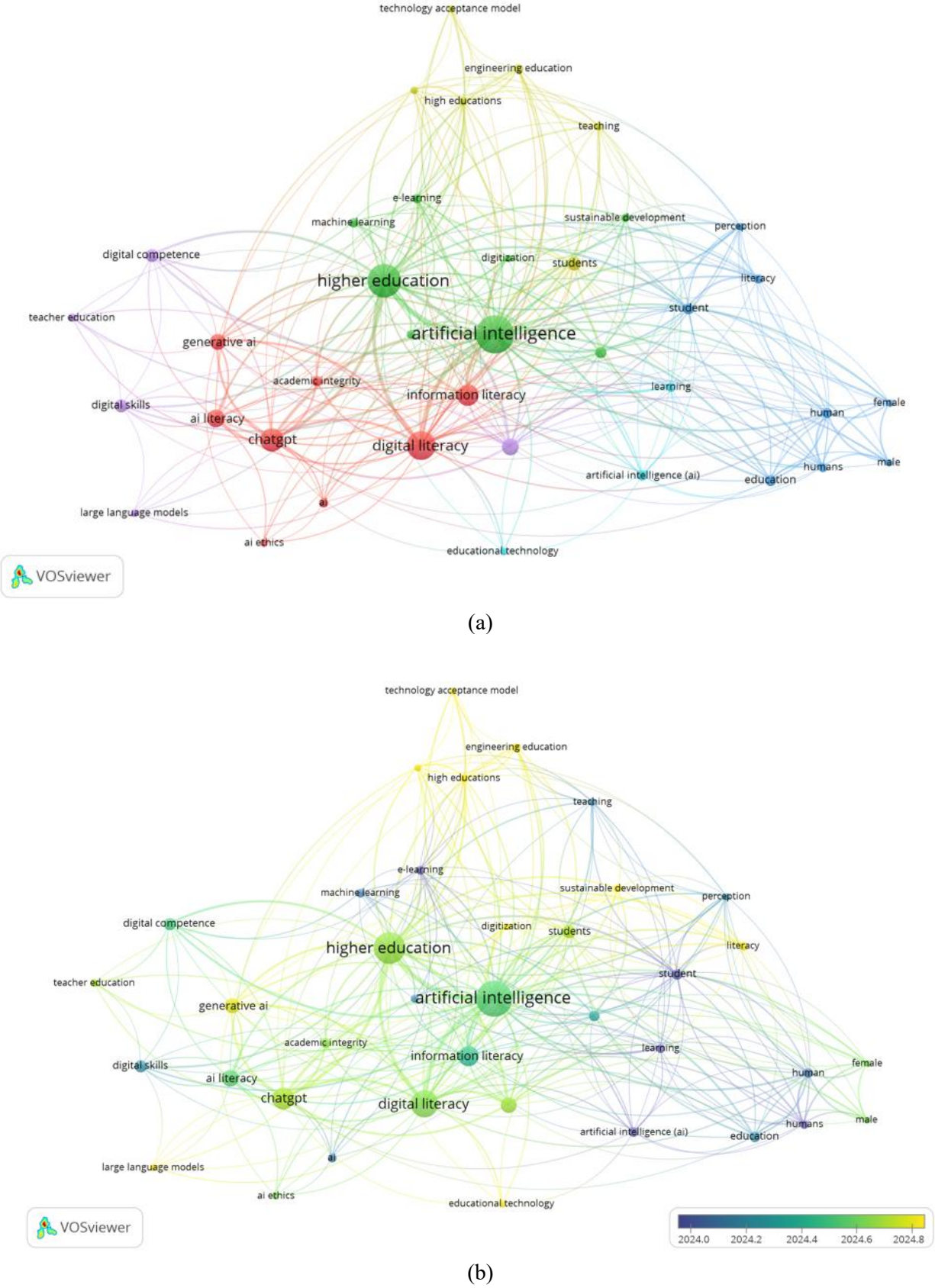


Figure 6. (a) Co-occurrence (Network Visualization) and (b) Co-occurrence (Overlay)

Red Cluster: Generative AI (e.g. ChatGPT) is reshaping digital literacy and its implications for the academic integrity and ethics of AI in higher education.

The red cluster shows a shift in discourse towards normative implications and the impact of generative technology in educational practice. Where the development of generative artificial intelligence (AI) technology, such as ChatGPT, has significantly reconstructed the concept of digital literacy in higher education. Digital literacy is no longer limited to basic technical skills, but has evolved into crisis literacy that includes the ability to evaluate AI-generated content, understand algorithmic biases, and use technology responsibly [34], [35], [36]. In addition, the emergence of AI literacy as a new competency requires students to be able to verify information and use AI ethically, although this level of readiness is still in its early stages [37], [38]. On the other hand, this technology also opens up opportunities through personalized learning, improved academic efficiency, and more dynamic content production, although it is still faced with the challenges of uneven access gaps and digital literacy [39], [40].

However, the use of generative AI also has serious implications for academic integrity and educational ethics. The use of AI for academic tasks such as authoring, summarizing, and idea development increases the risk of plagiarism, abuse, and overdependence that can weaken students' critical thinking skills [34], [41], [42]. In addition, limitations in citation practices to AI-generated content challenge conventional academic standards and demand more innovative evaluation approaches [41], [43]. From an ethical perspective, content such as algorithmic bias, data privacy, and inequality of access to technology are the main challenges in the integration of AI in higher education (Buragohain & Chaudhary, 2025; Mariyono & Alif Hidayatullah, 2025). Therefore, educational institutions need to develop comprehensive policies, encourage critical AI literacy, and ensure fair, transparent, and responsible implementation of technology [43], [47].

Green cluster: Artificial intelligence drives digital transformation and sustainable development in the higher education system.

Green clusters affirm their role as the conceptual foundation that connects the entire research domain. Where the use of artificial intelligence (AI) has become the main driver of digital transformation in the higher education system by fundamentally changing the process of learning, teaching and institutional management. AI enables personalized learning through adaptive platforms, real-time feedback, and a more flexible curriculum [19], [48]. In addition, AI improves operational efficiency through the automation of administrative processes and the use of technologies

such as chatbots to support academic services [49], [50] while encouraging collaboration in the digital learning ecosystem [51].

On the other hand, AI contributes to sustainable development by improving resource efficiency, expanding access to education and supporting the achievement of the Sustainable Development Goals (SDGs) (Ferk Savec & Jedrinović, 2025; van Wyk, 2025). However, challenges such as ethical issues, data privacy, algorithmic bias and the digital divide are still major concerns [22], [55]. Therefore, a comprehensive policy and strategic implementation that is inclusive is needed to ensure the effective and sustainable use of AI in higher education.

Blue cluster : Students perceptions and human centered factors influence the adaption and effectiveness of AI based learning in higher education.

The blue cluster highlights the human-centered dimension through student, human and perception which indicates an increased focus on user experience and interaction. Student perception and human centered factors play an important role in determining the adoption and effectiveness of artificial intelligence (AI)-based learning in higher education. Satisfaction, ease of use, and perception of usability are the main factors that increase engagement and learning outcomes [56], [57]. In addition, trust in the system and the level of AI Literacy also influence the use of technology, although issues such as accuracy, fairness, privacy and algorithmic bias are still obstacles [58], [59], [60].

On the other hand, the design of an adaptive, personalized, and interactive AI system has been proven to increase students' cognitive and emotional engagement [61], [62], including through features that resemble human interaction [63]. However, the limitations of interactivity and the need for human roles remain challenges. Therefore, strengthening AI literacy, user-based design, and balanced integration between technology and pedagogy are key in optimizing AI-based learning [64], [65].

Purple cluster : Digital competencies and teacher readiness affect the effective implementation of generative AI and large language models in higher education.

The purple cluster further emphasizes the urgency of human resource readiness. Digital competence and educator readiness are key factors in determining the effectiveness of the implementation of generative artificial intelligence (AI) and large language models (LLMs) in higher education. Educators are not only required to have technical skills, but also pedagogical competence in designing learning and utilizing AI critically and ethically [66], [67]. Although basic digital literacy is relatively high, there is still a gap in

framework are therefore needed to ensure effective and sustainable implementation of AI [81], [82]

4.5. Topic Modelling Analysis

Before modeling the topic using the Latent Dirichlet Allocation (LDA) method, the initial stage in content analysis involves creating a word cloud visualization to ensure that the text preprocessing process, including cleaning, normalization and tokenization has been done correctly. Word cloud visualization serves as a heuristic tool to identify the most frequently occurring term terms extracted from titles and abstracts, while validating thematic relevance that aligns with the research objectives.

As shown in figure 8, a number of dominant terms were successfully identified in the entire corpus, outside of the keywords that had been searched previously, the five most frequently appearing words were "ai" with 1006 occurrences, "students" (625), "digital" (622), "education" (491), "literacy (479). The dominance of this term confirms that the dataset used is very much filled with conceptual concepts that are relevant to this study. This dominance indicates that the main focus of the research lies in the integration of artificial intelligence in the context of higher education with a strong orientation on the development of students' digital literacy. In addition, the emergence of words such as learning, research, artificial, higher and intelligence reinforces that this field is multidisciplinary, combining technological perspectives, pedagogy and scientific research.

On the other hand, AI improves efficiency through the automation of student performance assessment and analysis, and supports data-driven decision-making [50], [52]. It also expands access to learning, although it still faces challenges such as ethical issues, privacy and technology dependency [79], [80]. Institutional readiness, educator training and a strong ethical



Figure 7. Word Cloud

To ensure the statistical validity of thematic extraction, LDA mode is executed through a rigorous processing flow, including word stop removal, character competition, and WordNet Lemmatization to ensure morphological consistency. Bigram handling is also applied to maintain the semantic integrity of the term "Artificial Intelligence". The number of $k=10$ optimal topics was strictly determined through the evaluation of the Coherence Score (Cv) and confusion metrics [83] This systematic approach ensures that the ten topics presented in Table 2 are semantically different and have high interpretability in analyzing the relevance of artificial intelligence to improve digital literacy in higher education

Table 2. LDA Topics, Representative Keywords, and Interpretations

Topic	Topic Label	Representative Keywords	Interpretation
1	Ai-Driven Digital Literacy in Higher Education	Ai, digital, education, study, learning, higher, student, etihcal, research, literacy	Focuses on the integration of AI technologies to enhance digital literacy competencies in higher education
2	Critical Thinking and Academic writing with AI	Ai, crtical, students, chatgpt, thingking, study, literacy, ethical, university, writing	Examines the role of AI tools in supporting academic writing and critical thinking development.
3	AI-Supported collaborative and self regulated learning	Learning, ai, students, group, skills, self, based, using, education	Highlights AI-assisted collaborative learning and learner autonomy.
4	AI adoption and data driven education systems	Education, research, study, digital, data, higher, artificial, intelligence, adoption, students	Explores institutional AI adoption and data-driven transformation in higher education.
5	Generative AI and academic practices	Students, ai, use, academic, tools, chatgpt, study, generative, writing, literacy	Investigates the growing use of generative AI technologies in academic activities.
6	Teachers' attitudes an digital literacy development	Digital, ai, students, literacy, education, teachers, attitudes, study, skill, intelligence	Focuses on educator readiness and attitudes toward AI integration
7	Ai in online and digital teaching environments	Digital, learning, ai, teaching, students, online, education, study, student, teacher	Discusses AI-supported online and hybrid learning environments.
8	AI and digital competencies development	Digital, students, learning, skills, artificial, education, intelligence, ai, study, competencies	Examines AI-supported development of digital competencies and 21st-century skills.
9	AI in information literacy and library systems	Literacy, information, ai, libraries, intelligence, research, education, technology, paper	Investigates AI integration in information literacy education and digital library systems
10	AI research trends and competency in higher education	AI, research, study, digital, students, artificial, intelligence, universities, competence	Identifies emerging research directions and competency development in higher education

As presented in Table 2, the ten topics reveal a diverse yet interconnected research landscape. The themes identified ranged from AI-based digital literacy and generative AI applications to educator readiness, information literacy systems, and competency development, suggesting that research in this area has evolved beyond technology adoption towards broader pedagogical, ethical, and institutional considerations.

Marginal topic probability visualization shows the proportion distribution of each topic in the research corpus, where topic 5 emerged as the most dominant theme ($=0.22$), followed by topic 1 ($=0.19$) and topic ($=0.15$), while other topics such as topic 2 and topic 7 had relatively low contributions (<0.03). The dominance of 5 topics related to generative AI and academic practice confirms that the current discourse is very focused on the use of technologies such as ChatGPT in academic activities, specifically writing and the use of AI tools. Meanwhile, the strength of Topic 1 and Topic 6 shows that the issue of AI-based digital literacy as well as the role of teachers and attitudes towards AI remain important foundations for researchers. On the other hand, the low proportion of Topic 2 (critical thinking and academic writing with AI) suggests that although issues of critical thinking and ethics are beginning to emerge, this field is still developing and has not yet become a major requirement.

Overall, this distribution reinforces the results of previous topic modelling that showed that the research landscape is dominated by the practical integration of AI and digital literacy, with a gradual shift towards more reflective ethical and pedagogical dimensions.

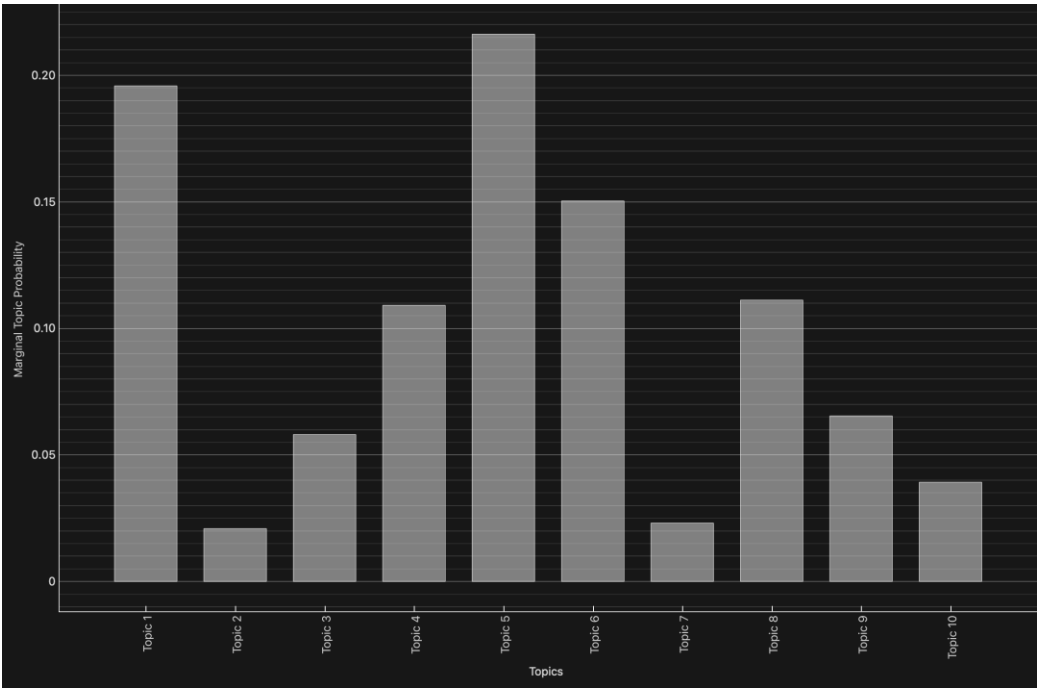


Figure 8. Marginal Topic Probability (MTP)

The Multimensional scaling (MDS) visualization shows two main thematic relationships, namely between topics 1 and 6 and topic 4 and topic 8, which is reflected in the proximity of their positions, the proximity of topic 1 (AI-driven digital literacy) and topic 6 (teachers' attitudes and digital literacy development) emphasizes that the development of AI-based digital literacy is highly dependent on the role and readiness of educators as key actors. Meanwhile, the relationship between topic 4 (AI adoption and data

driven education systems) and Topic 8 (AI and digital competencies development) shows that the adoption of AI in the education system directly encourages the strengthening of digital competencies. Overall, these two relationships present two main axes in the intellectual structure of research, namely human-centered integration through the role of educators and system-based transformation through the development of digital competencies.

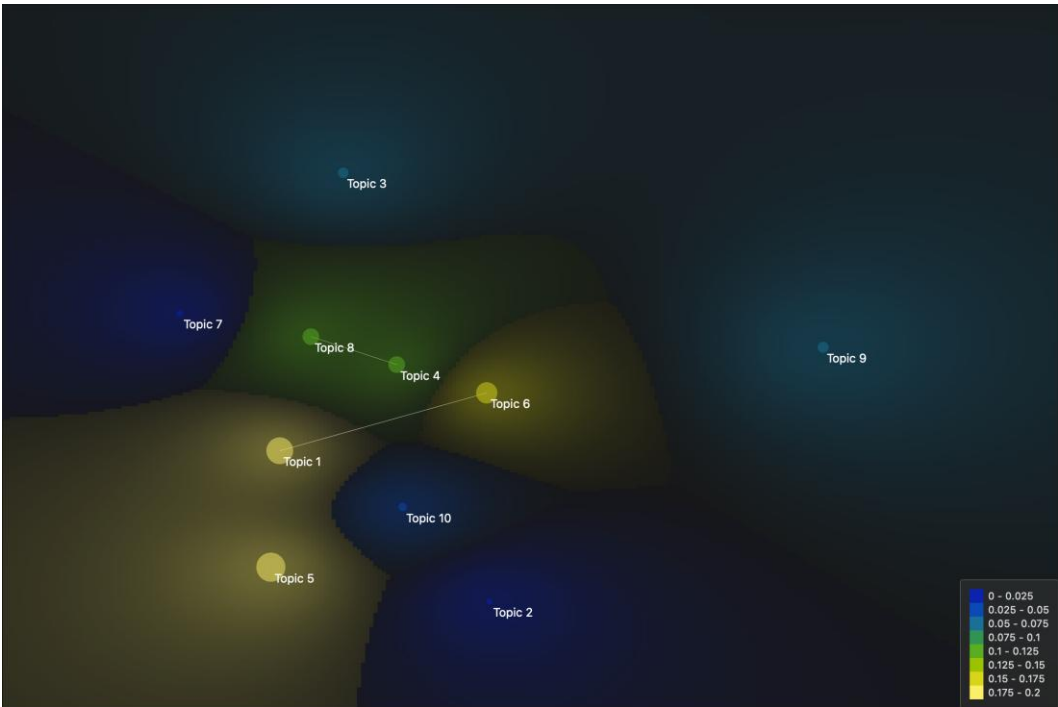


Figure 9. Multidimensional Scaling (MDS)

Table 3. summarizes these emerging trends and suggests pathways for sustainable digital literacy development.

Topic	Emerging Research Trends	Future Directions
Topic 1	Ai-driven digital literacy integration in higher education	Develop curriculum models integration AI literacy with critical and etihcal competencies
Topic 2	Generative AI (e.g., ChatGPT) in academic writing and critical thingking	Design assessment framework that balance AI use with academic integrity an critical thingking skills
Topic 3	AI supported collaborative and self regulated learning	Expand adaptive and collaborative learning models using AI to enchanche students autonomy
Topic 4	AI adoption and data driven transformation in higher education systems	Insvestigate institutional strategies for scable and sustainable AI implementation
Topic 5	Generative AI tools in academic practice and students productivity	Explore etihcal guidelines and pedagogical models for responsible use of generative AI
Topic 6	Teachers' readiness and attitudes toward AI integration	Develop professional development programs to enhace AI pedagogical competence among educator
Topic 7	AI-enhanced online and digital learning enviroments	Advance hybrid and intelligent learning enviromentas integrating AI and online learning systems
Topic 8	Development of digital competencies and 21st century skills trough AI	Design competency based frameworks aligned with AI driven education ecosystems
Topic 9	AI in information literacy and digital knowledge systems	Stregthen AI integration in digital libraries and information literacy education
Topic 10	AI research trends and competency development in universities	Promote interdisciplinary and transnational research on AI in higher education

In summary, integrative analysis shows that there is a dominant focus on digital literacy based on artificial intelligence, the use of generative AI, and the transformation of learning and teaching practices in higher education. Through a combination of topic modelling, keyword co-occurrence analysis and temporal analysis, it can be seen that current research prioritizes the development of an adaptive, evidence-based and technology-supported learning environment. However, there are still significant gaps in the deeper pedagogical integration of AI, especially in the development of higher-level thinking skills, critical literacy, and long-term learning outcomes, which are still relatively underexplored and not yet conceptually integrated. This gap underscores the need for a more comprehensive AI-based Education framework, multidisciplinary collaborations and longitudinal research to ensure that AI adoption not only improves technological efficiency, but also contributes meaningfully to the development of sustainable, masuia-centric digital literacy in higher education.

5. Conclusion

Based on the results of the *Systematic Literature Network Analysis* (SLNA) of 242 articles, this study shows that the field of *Artificial Intelligence for Digital Literacy in Higher Education* has experienced very rapid growth, especially since 2023 in line with the development of *generative AI* technology. The intellectual structure of the research is formed multidimensional through six main clusters which include aspects of AI-based digital literacy, ethics and academic integrity, human-centered factors, pedagogical adoption, digital competence, and

integration of learning technologies. These results confirm that AI no longer only serves as a technical tool, but has become a core element in the transformation of the higher education ecosystem.

In addition, the topic modelling analysis identified ten main themes with a predominance on the use of generative AI in academic practice, indicating a shift in research focus towards practical and contextual applications. These findings also reveal a paradigm shift from a technology-based approach to a more human-centered approach, with increased attention to ethical aspects, critical literacy, and user experience. Nevertheless, there are still significant gaps in the deep pedagogical integration of AI, particularly in the development of high-level thinking skills and sustainable long-term learning.

Overall, this research makes an important contribution in mapping the scientific landscape and offers a strategic direction for future research development, including the need to strengthen multidisciplinary collaboration, develop a comprehensive AI-based curriculum, and adaptive and ethical policymaking to ensure inclusive, sustainable, and significant impact AI implementation in higher education.

Declarations

Author Contributions

Conceptualization, R. and F.A.; methodology, D.M. and J.H.; software, R. and J.H.; validation, S.A. and R.; formal analysis, R. and F.A.; investigation, D.M. and A.I.; resources, J.H.; data curation, R. and S.A.; writing original draft preparation, R.; writing review and editing, J.H.; visualization, J.H.; supervision, J.H. All

authors have read and agreed to the published version of the manuscript.

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"Not Applicable" for studies not involving humans or animals.

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Conflicts of Interest

The author declares that there is no conflict of interests regarding the publication of this manuscript.

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