Jurnal Pendidikan Progresif
e-ISSN: 2550-1313 | p-ISSN: 2087-9849
URL: https://jpp.fkip.unila.ac.id/index.php/jpp
Jounal's DOI: http://doi.org/10.23960/jpp

Vol. 16, No. 1, 2026
Article ID: 1071
Pages: 318-344

Mapping the Evolution of Lifelong Learning, Technology, and E-Learning Research: A Bibliometric Analysis

Firdaus[1], Ishaq[2], Muhammad Amin Said[3], & Syamsidar Saleng[4,*]
[1]Department of Sociology Education, Universitas Muhammadiyah Makassar, Indonesia
[2]Department of Physics Education, Universitas Muhammadiyah Makassar, Indonesia
[3]Department of Primary Teacher Education, Universitas Muhammadiyah Makassar, Indonesia
[4]Doctoral Student, Education Study Program, Universitas Muhammadiyah Makassar, Indonesia

*Corresponding email: syamsidars@unismuh.ac.id

Received: 22 August 2025 *Accepted: 30 October 2025* *Published: 15 February 2026*

Abstract: The rapid expansion of digital technologies has transformed the way lifelong learning and e-learning are understood and practiced. This study undertakes a bibliometric analysis to trace the evolution of research on lifelong learning, technology, and e-learning from 2011 to 2024, offering a comprehensive view of the field's intellectual and developmental trajectory. A total of 624 documents indexed in the Scopus database were analyzed using VOSviewer and Biblioshiny. The analysis included annual publication trends, leading source titles, influential authors, contributing countries, thematic keywords, and conceptual structures. Temporal mapping was employed to identify the main developmental phases of the field. The analysis reveals three distinct phases of publication growth. The first phase (2011–2015) centered on digital infrastructure and the early adoption of ICT in education. The second phase (2016–2019) saw increased attention to integrating e-learning platforms and developing lifelong learning competencies. The third phase (2020–2024) experienced a sharp surge in output, largely driven by educational shifts following the COVID-19 pandemic, as well as emerging discussions about artificial intelligence, digital transformation, and adaptive learning systems. An unexpected yet striking observation was the accelerated rise of AI-related research after 2021. Throughout these periods, enduring themes such as e-learning, lifelong learning, and digital competence remained central. At the same time, the diversity of authors, journals, and contributing countries underscored the field's interdisciplinary and global character. This study highlights a structural shift from technology-centered approaches to learner-focused and adaptive pedagogies. Two major insights stand out. First, the COVID-19 pandemic catalyzed the rapid global expansion of research and investment in digital learning. Second, the growing prominence of artificial intelligence signals an emerging shift toward intelligent, personalized lifelong learning ecosystems. A notable limitation of this work is that, although the dataset extends to mid-2025, the core analysis focuses on publications from 2011 to 2024 because data for 2025 remain incomplete. The partial records from 2025 are therefore presented only as preliminary signals of developing research directions and should be interpreted with due caution.

Keywords: lifelong learning, e-learning, digital competence, artificial intelligence, bibliometric analysis.

Article's DOI: https://doi.org/10.23960/jpp.v16i1.pp318-344

INTRODUCTION

The rapid advancement of information and communication technologies (ICT) has profoundly transformed many aspects of society, especially education. Digital learning, valued for its accessibility, flexibility, and adaptability, has become indispensable, especially in lifelong learning (Jhanwar & Sadaria, 2025). Lifelong learning, understood as the continuous pursuit of knowledge and skills across one's lifespan, plays a critical role in fostering personal development and professional adaptability in an ever-changing

labor market (Stefan et al., 2023; Vonitsanos, Moustaka, Doukakis, & Mylonas, 2024). The integration of information and communication technologies (ICT) into education has transformed pedagogical practices, promoting more interactive, inclusive, and personalized forms of learning (Kummanee, Nilsook, Piriyasurawong, & Wannapiroon, 2023; Savchenko, Synytsya, & Synyakova, 2023). This ongoing transformation contributes to addressing global challenges such as educational inequality, the digital divide, and the growing need for continuous professional development amid rapid technological change (Bulathwela, Pérez-Ortiz, Holloway, Cukurova, & Shawe-Taylor, 2024).

The COVID-19 pandemic accelerated the widespread adoption of digital learning platforms, underscoring their critical role in sustaining educational continuity during periods of disruption (Kapoor, Chahal, Sharma, Kaur, & Hendrik, 2025). Education 4.0, which emphasizes digital transformation in education, advocates integrating advanced digital tools to create flexible, inclusive lifelong learning opportunities (Vonitsanos et al., 2024). Recent innovations have substantially advanced adult education, particularly in remote learning, interdisciplinary collaboration, and the cultivation of digital competencies required in today's labor markets (Mungra, Srivastava, Sharma, Banerji, & Gollapudi, 2024; Segura, Garrido, Morueta, & Miranda, 2023). Despite the increasing adoption and recognition of digital learning technologies, a critical knowledge gap persists regarding how research on lifelong learning, technology, and e-learning has evolved. Previous studies have tended to focus on specific aspects, such as digital competence (Blank & Schmidt, 2022), learner motivation and technology acceptance (Yan et al., 2024), or the influence of MOOCs (Gouws & Kritzinger, 2023). However, a comprehensive understanding of research trajectories, leading contributors, and thematic progressions remains limited. This gap underscores the need for a bibliometric approach, a quantitative technique for systematically examining publication patterns, influential scholars, leading journals, geographic distributions, and keyword dynamics (Zhang, Li, Pan, Zhai, & Li, 2023). Such an approach enables a structured mapping of the field, revealing pivotal developments and offering insights that can inform future research directions. It also provides valuable guidance for scholars, policymakers, and educational institutions seeking to align learning strategies with evolving digital demands (Skvarc & Markulin, 2024). Bibliometric analysis has proven effective in capturing the evolution of research landscapes, identifying key contributors, and tracing thematic developments. Recent educational studies have employed this method to examine the post-pandemic rise of digital learning, emphasizing themes such as flipped classrooms, blended learning, and digital equity (Zhang et al., 2023). Other works have explored institutional digital maturity and the outcomes of ICT investment (Skvarc & Markulin, 2024). For instance, Wang et al. (2024) applied bibliometric techniques to investigate the role of e-learning in corporate training, highlighting both its theoretical depth and practical significance. In medical education, bibliometric mapping has clarified the transition from emergency remote instruction to blended learning models (Zhang et al., 2023). Similarly, studies on digital self-efficacy have provided conceptual frameworks that inform research on digital competence (Blank & Schmidt, 2022). Collectively, these studies demonstrate the strength of bibliometric analysis in integrating diverse evidence, revealing intellectual structures, and setting informed research agendas.

Many previous studies have taken a narrow focus or lacked methodological integration, thereby overlooking broader trends and collective insights within the field (Savchenko et al., 2023; Yamin, Imran, & Katt, 2023). Most have

examined only specific dimensions, such as digital competence (Blank & Schmidt, 2022) learner motivation and technology acceptance (Yan et al., 2024), or the adoption of MOOCs as isolated innovations v (Gouws & Kritzinger, 2023). These fragmented perspectives fail to capture longitudinal patterns in publication growth, contributors, cross-national collaborations, and the evolution of research themes over time. In contrast, the present study adopts an integrative bibliometric approach encompassing 624 Scopus-indexed documents published between 2011 and 2025. This comprehensive analysis offers a synthesized view of publication dynamics, authorship, source impact, geographic distribution, and conceptual development across the fields of lifelong learning, technology, and e-learning. Notably, detailed bibliometric mappings of outputs, contributors, geographic trends, and thematic evolution during these 15 years remain limited in the existing literature, creating a gap that this study seeks to address. To fill that gap, this research conducts a systematic bibliometric assessment of scholarly developments across the identified domains. It examines publication growth, influential authors, leading journals, national and international contributions, keyword trends, and thematic directions, drawing on peer-reviewed, Scopus-indexed literature. The novelty of this study lies in its comprehensive and integrative scope, which consolidates previously scattered findings into a unified analytical framework. Through this synthesis, the study delineates long-term publication trajectories, identifies key contributors and influential journals, maps collaborative networks, and traces thematic evolution from 2011 to 2025, offering a coherent perspective on the intellectual structure of research in lifelong learning and e-learning.

In doing so, the study not only integrates disparate insights but also establishes a structured basis for guiding future scholarly inquiry in lifelong learning, technology, and e-learning. By excluding non-peer-reviewed sources, the research ensures methodological rigor and academic reliability. This investigation is guided by six central research questions:

1. How do annual publication trends and citation dynamics demonstrate the global growth and shifting emphasis of research on lifelong learning, technology, and e-learning?
2. Which source titles and publication outlets (e.g., ACM, CEUR, BJET, *Sustainability*) have played the most significant role in shaping discourse and dissemination within this field?
3. Which authors have emerged as the most prolific and influential within the field, and in what ways have their contributions evolved with respect to productivity, citation impact, and thematic focus?
4. How do countries vary in their research output and collaboration networks, and what do these variations reveal about differences in national research capacity, funding priorities, and policy environments?
5. What keyword clusters and co-occurrence networks reveal the dominant, emerging, and declining themes that structure this research domain?
6. How does the thematic landscape, including continuity, transformation, and the evolution of research fronts, illustrate the intellectual structure and future trajectories of lifelong learning and e-learning scholarship?

METHOD

Research Design

This study adopts a bibliometric research design to systematically map and evaluate scholarly developments in lifelong learning, technology, and e-learning. The bibliometric approach was chosen because it enables both quantitative and visual analyses of large-scale publication data, allowing the identification of structural patterns, thematic evolution, and key

contributors within the field. The design maintains methodological rigor by relying solely on Scopus-indexed, peer-reviewed literature published between 2011 and 2025, thereby ensuring analytical consistency, reliability, and academic validity.

Search Strategy

Bibliometric data were collected from the Scopus database (https://www.scopus.com), a widely recognized and reliable source with comprehensive coverage of academic publications (Visser, van Eck, & Waltman, 2021). Data retrieval was performed electronically on July 6, 2025, using a Boolean search query applied to the title, abstract, and keyword fields with the terms *"Lifelong Learning,"* *"Technology,"* and *"e-learning"* (TITLE-ABS-KEY). These keywords were selected to capture the intersection of continuing education and digital pedagogy. Although the query was designed to be comprehensive, it may have omitted studies that use alternative terminology, such as *"digital education"* or *"online pedagogy,"* which represents a limitation of the dataset. The initial search yielded 624 documents. The subsequent screening and selection process adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological transparency and reproducibility. Figure 1 illustrates the PRISMA flow diagram, detailing the number of records identified, screened, and included at each stage of the selection process.

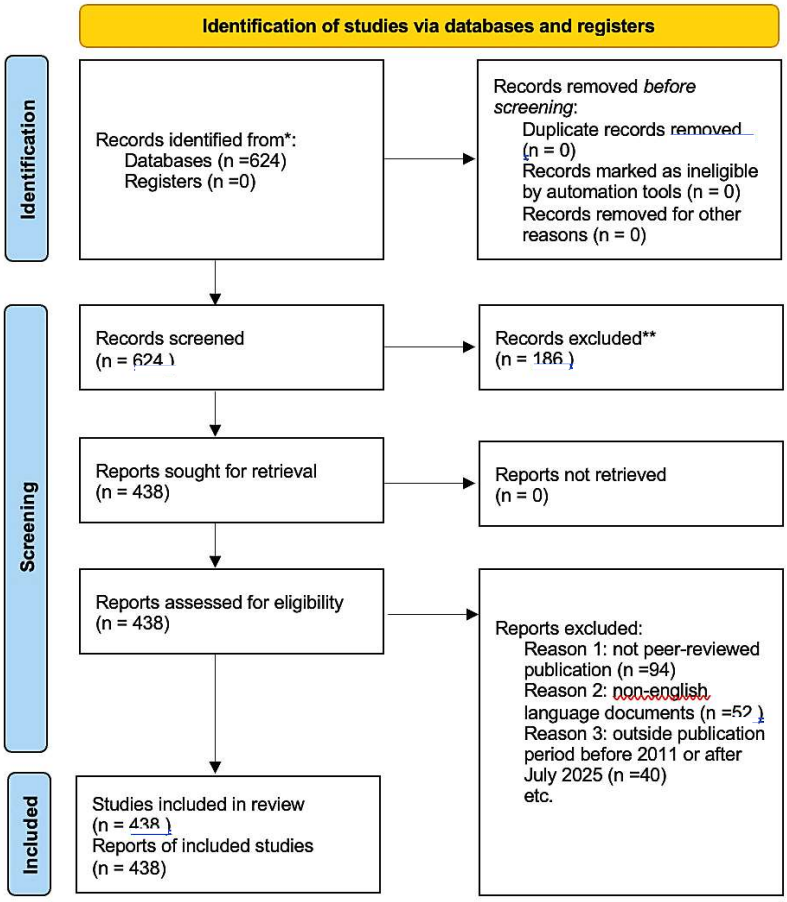

Figure 1. PRISMA flow diagram of the literature selection process

Inclusion and Exclusion Criteria

The inclusion criteria were restricted to peer-reviewed journal articles and conference papers published between 2011 and 2025, written in English, indexed in Scopus, and directly addressing lifelong learning, technology, and e-learning. Exclusion criteria comprised non-peer-reviewed materials (e.g., editorials, reports, or book reviews), documents outside the defined time range, non-English publications, and duplicate or incomplete records. After applying these criteria, 438 documents were retained for analysis. This reduction from the initial 624 records resulted from the screening and eligibility refinement process. To ensure consistency, all subsequent analyses, results, and interpretations in this study are based on the final dataset comprising 438 documents.

Data Analysis

Microsoft Excel was employed for data preprocessing and descriptive statistical analysis, VOSviewer was utilized to visualize co-occurrence networks and clustering patterns, and Biblioshiny, the web interface of the Bibliometrix R package, was applied for advanced analyses, including thematic evolution and source impact (Aria & Cuccurullo, 2017; Aria, Cuccurullo, D'Aniello, Misuraca, & Spano, 2024). The study evaluated four key aspects: (1) productivity (annual publication growth, source title frequency, author productivity, and h-index), (2) impact (citation counts and journal influence), (3) collaboration (co-authorship and international linkages), and (4) conceptual structure (keyword co-occurrence and thematic evolution). Keyword dynamics were further analyzed across four intervals (2011–2014, 2015–2018, 2019–2022, and 2023–2025) to assess thematic progression. Because data collection ended in July 2025, records from that year and, to some extent, from late 2024 may be incomplete, which represents a limitation of the study. To maintain methodological focus, references to bibliometric laws such as Bradford's, Lotka's, and Zipf's were omitted from this version unless directly supported by specific analyses in the results.

■ RESULT AND DISCUSSION

Global Publication Trends and Research Growth

Figure 2 illustrates the annual publication output on lifelong learning, technology, and e-learning from 2011 to 2025, highlighting shifting patterns of scholarly interest over this period. Based on 624 documents indexed in the Scopus database, the findings reveal three distinct phases of publication activity: an initial phase of moderate growth, a middle phase characterized by a temporary decline, and a sharp surge following the COVID-19 pandemic. Between 2011 and 2014, annual publication counts ranged from 26 to 32, peaking at 32 in 2013. A notable decrease followed in 2014, with only 19 publications recorded. From 2015 to 2020, overall output remained relatively modest, fluctuating between 18 and 26 publications, with the lowest point observed in 2017 (18 articles). This trend likely reflects a transitional period characterized by experimentation and shifting priorities in digital education, preceding the broader adoption of remote learning technologies.

A sharp rise in publication activity was recorded in 2021, reaching 47 articles, the highest output across the entire study period. This surge coincides with the global emphasis on digital and distance learning prompted by the COVID-19 pandemic. Scholarly engagement remained strong throughout 2022 and 2023, with both years also producing 47 publications, indicating sustained academic interest in educational technology and lifelong learning initiatives. In 2024, output declined slightly to 39 articles, followed by a more pronounced drop to 12 in 2025, likely reflecting the incomplete indexing of publications for that year. This pattern aligns with Kapoor et al. (2025),

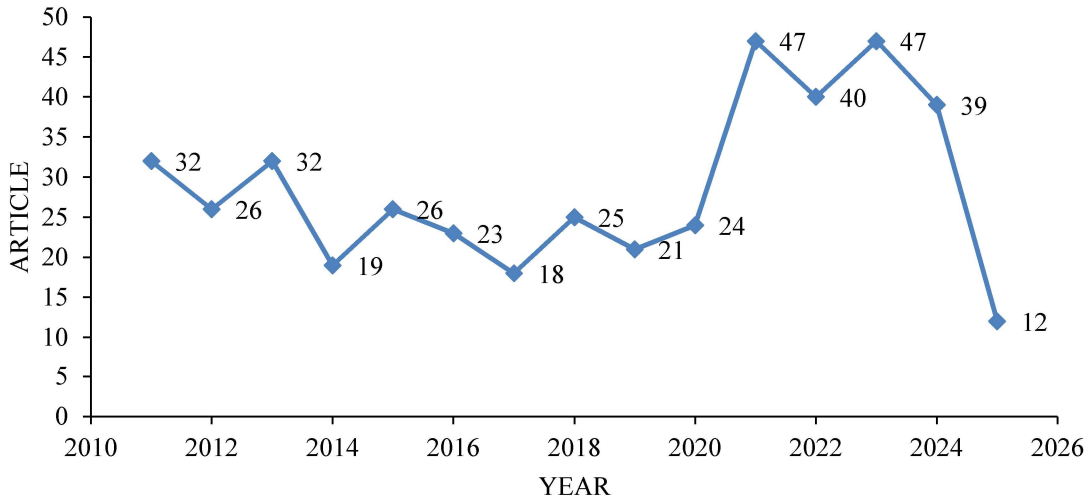

Figure 2. Annual publication trends in lifelong learning, technology, and e-learning from 2011 to 2025

who underscored the pandemic's catalytic role in accelerating the adoption of digital learning across education systems. The trajectory also supports the observations of Wang & Wang (2024) and Zhang (2023), who noted the rapid expansion of digital integration in education since 2020. The post-pandemic acceleration in publication volume underscores the urgency to rethink pedagogical approaches through technology-enhanced frameworks (Jhanwar & Sadaria, 2025). This pattern indicates that global crises serve as accelerators of research priorities, prompting policymakers to invest in digital infrastructure and pushing researchers to move beyond descriptive mapping toward studies that examine equity, sustainability, and long-term educational impact.

Overall, the trend underscores a growing global research interest in digital education, particularly as a response to pandemic-related disruptions and the broader shift toward Education 4.0. These publication dynamics reflect not only the transformation of the educational landscape but also the rising importance of lifelong learning and e-learning in addressing contemporary societal and technological challenges.

This trajectory suggests that global crises can act as accelerators of research priorities, redirecting scholarly focus toward pressing pedagogical and technological innovations. The post-2020 surge demonstrates how the pandemic reshaped educational agendas worldwide, positioning lifelong learning and e-learning as strategic frameworks for navigating uncertainty. For policymakers, this highlights that investment in digital infrastructure and research capacity has become essential rather than optional. For researchers, it signals that the field is entering a more mature phase that demands a shift from descriptive mapping to a critical evaluation of the impact, equity, and sustainability of technology-enhanced education.

Beyond the overall growth in publication volume, it is equally important to identify which source titles have been most influential in shaping the discourse. Figure 3 illustrates the cumulative publication trends of five key sources contributing to research on lifelong learning, technology, and e-learning between 2011 and 2025. The analysis reveals distinct growth trajectories and varying degrees of influence among publication venues. The *ACM International Conference Proceedings Series* is the most prolific outlet, exhibiting steady growth since 2011 and a notable surge beginning in 2020. By 2022, it surpassed 17 cumulative occurrences and maintained this momentum through 2025. This pattern

underscores ACM's pivotal role in disseminating research at the intersection of computing and education, particularly during the digital transformation accelerated by the COVID-19 pandemic. Similarly, the *CEUR Workshop Proceedings* exhibit a pronounced upward trend, especially since 2018, reflecting their growing relevance as platforms for emerging interdisciplinary scholarship. The source had published more than 13 papers by 2023 and maintained this output, indicating its growing relevance in applied technology and lifelong learning research, particularly in open-access contexts.

Overall, the data in Figure 3 underscore the importance of ACM and CEUR Workshop Proceedings as leading venues for dissemination. Their growing output signals robust engagement with themes of digital education and lifelong learning within the computing disciplines. The high impact of journals such as the *British Journal of Educational Technology* and *Sustainability (Switzerland)*, despite lower overall output, reflects a shift toward sustainability and socially impactful research (Bulathwela et al., 2024). These results affirm the need for cross-disciplinary publishing strategies that merge educational relevance with technological depth.

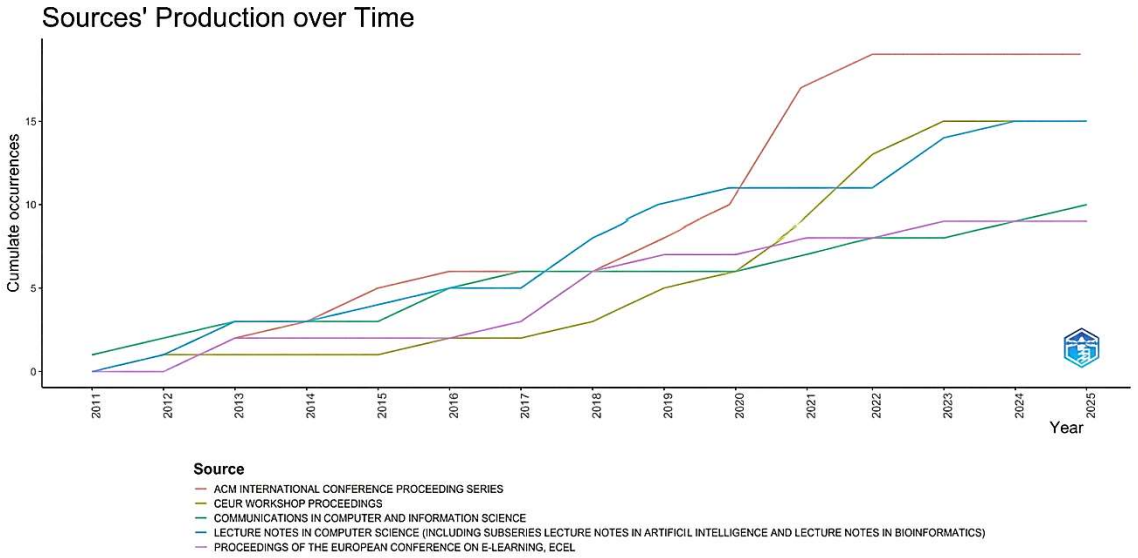

Figure 3. Sources' publication trajectories (2011–2025)

Lecture Notes in Computer Science (LNCS), including its subseries in Artificial Intelligence and Bioinformatics, has shown consistent contributions, with a noticeable increase since 2020. The series stabilized at more than 10 publications in 2023, reaffirming its role in fostering interdisciplinary approaches that link computer science and digital pedagogy. *Communications in Computer and Information Science (CCIS)* and the *Proceedings of the European Conference on E-Learning (ECEL)* display slower yet consistent growth across the examined period. While CCIS has contributed steadily throughout the timeline, ECEL represents a distinctly European-centered discourse that connects education, technology, and policy within digital contexts.

Overall, the data in Figure 3 highlight the prominence of the ACM International Conference Proceedings Series and the *CEUR Workshop Proceedings* as leading platforms for

disseminating research on lifelong learning and digital education. Their sustained output reflects strong scholarly engagement with interdisciplinary themes at the intersection of computing and education. These trends further indicate a broader transition toward cross-disciplinary publication practices and a global prioritization of educational innovation amid rapid technological change. Collectively, these developments suggest that influential contributions in the field are increasingly published through interdisciplinary venues. For researchers, this highlights the strategic importance of targeting publication outlets that integrate technical rigor with pedagogical relevance, thereby enhancing both academic visibility and policy impact. While Figure 3 illustrates the growth trajectories of major publication venues, Figure 4 shifts the analytical focus toward the intellectual landscape, mapping how countries, authors, and research themes interconnect within this evolving scholarly domain.

Geographic Distribution and Collaboration Patterns

Figure 4 presents a three-field plot illustrating the relationships among countries of authorship (AU_CO), individual authors (AU), and dominant research themes or keywords (DE) in publications on lifelong learning, technology, and e-learning from 2011 to 2025. This visualization, based on 624 Scopus-indexed documents, maps both the thematic focus and the geographic distribution of scholarly activity. On the left axis, the plot highlights the contributing countries. The United States, China, the United Kingdom, and Germany appear as the most prolific producers of academic output in this field, reflecting their sustained investment in educational technology and digital learning infrastructure. Other notable contributors include Spain, India, Greece, Malaysia, and Latvia underscoring the increasingly global and collaborative nature of research in lifelong learning and e-learning

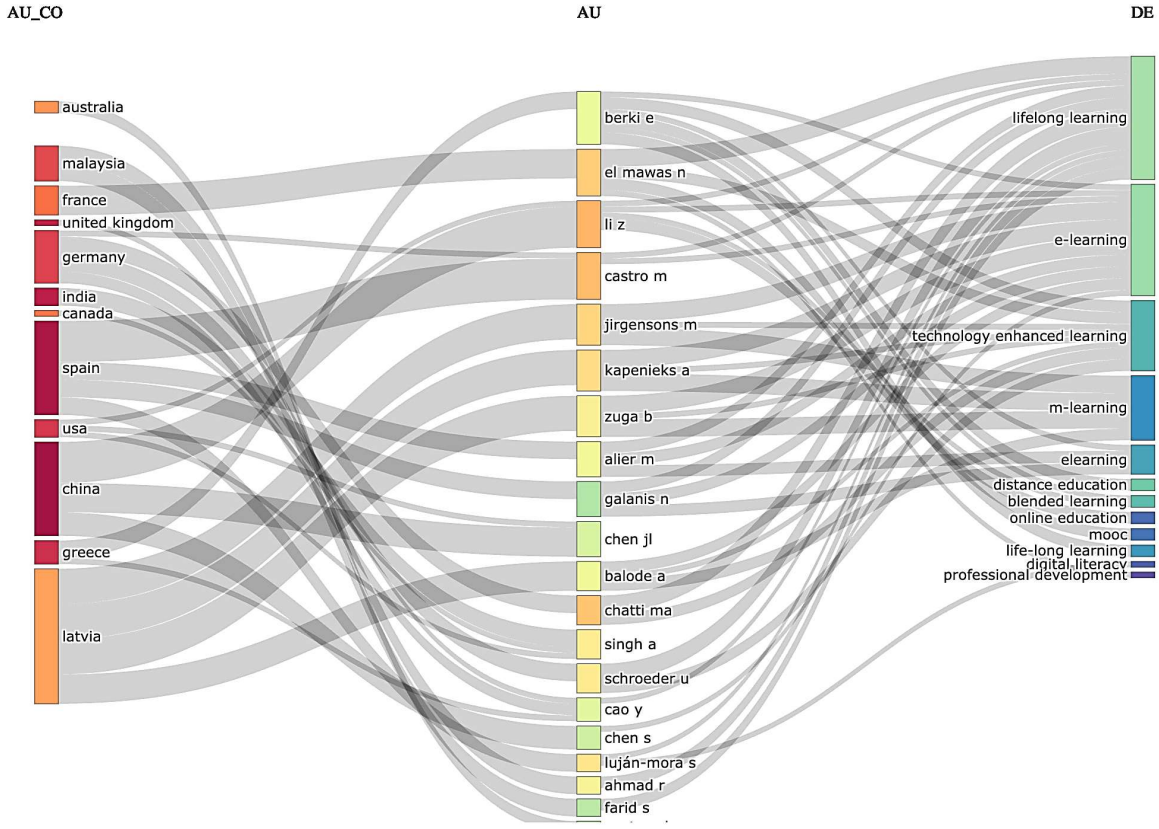

Figure 4. Three-Field plot of authors, author countries, and keywords

The central axis displays several prominent authors, including Berki E., El Mawas N., Li Z., Castro M., Jirgensons M., and Kapenieks A., each representing distinct research trajectories and thematic interests. Many of these scholars are affiliated with multiple countries, reflecting the increasingly international character of this research domain. For instance, Berki E. and El Mawas N. are closely linked to studies on lifelong learning and technology-supported education. In contrast, Li Z. and Castro M. focus more on e-learning and mobile learning. This distribution points to a clear pattern of specialization and thematic leadership among key contributors to the field. On the right axis, frequently occurring keywords such as *"lifelong learning," "e-learning," "technology-enhanced learning,"* and *"m-learning"* dominate the conceptual landscape. Additional terms, including "MOOC," "distance education," "blended learning," and "digital literacy," further illustrate the diversity of pedagogical models and digital frameworks explored across different contexts and regions. The visualization also highlights dense connections among particular countries, authors, and research themes, suggesting strong cross-national collaboration and thematic coherence. For example, Germany and the United Kingdom are closely linked to authors such as Berki E. and El Mawas N., whose work emphasizes pedagogical innovation in lifelong learning. Meanwhile, the United States and China exhibit significant connections to research on data-driven educational technologies, signaling a global convergence of digital learning priorities.

Figure 5 illustrates the scholarly productivity and citation impact of the most prolific authors contributing to research on lifelong learning,

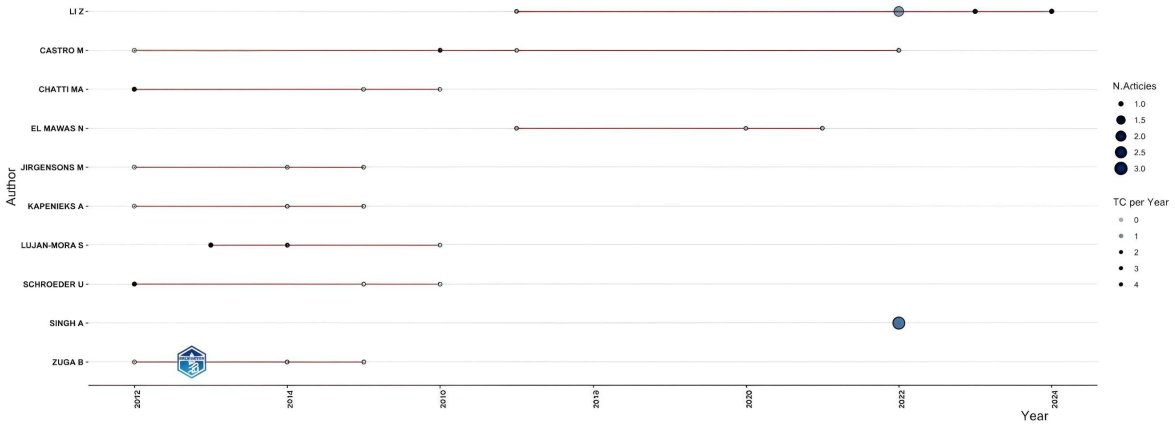

Figure 5. Authors' scholarly productivity over time

technology, and e-learning between 2011 and 2025. The timeline-based visualization combines two indicators: the number of publications (represented by circle size) and annual citation counts (indicated by color intensity). Together, these dimensions provide a dual perspective on authorial influence and research continuity. Among the identified authors, Li Z. stands out as the most consistently active, maintaining a stable publication record from the early 2010s through 2025. Their more recent works have received increasing citation attention, reflecting rising academic visibility and recognition. Castro M. and Chatti M. also show sustained engagement, with research activity extending across multiple years, particularly aligning with the global shift toward online and hybrid learning models after 2020. El Mawas N., Jirgensons M., and Kapenieks A. demonstrate concentrated productivity during the mid-2010s, indicating their strong involvement in shaping early frameworks of digital and technology-enhanced education.

In contrast, Zuga B. and Singh A. exhibit a focused burst of publication activity around 2022. Despite producing fewer papers, Zuga B.'s work records comparatively higher citation rates, suggesting concise yet impactful contributions. Luján-Mora S. and Schroeder U. maintain steady output with moderate citation levels, implying ongoing engagement that consolidates existing research directions rather than initiating new ones. Meanwhile, renewed activity from Singh A. and the continued presence of Kapenieks A. signal the emergence of newer leadership figures and evolving scholarly influence within the field.

These patterns of authorship and collaboration confirm that lifelong learning and e-learning research are shaped by both sustained contributors and emerging scholars. As noted by Yan et al. (2024), the balance between continuity and renewal is central to the adaptability of digital pedagogy research. The prominence of highly cited scholars further illustrates the field's gradual transition toward learner-centered paradigms and technology-driven educational models.

Table 1 presents the 10 most highly cited publications in the fields of lifelong learning, technology, and e-learning between 2011 and

Table 1. Highly cited lifelong learning, technology, and e-learning research

Rank	Title	Year	Source Title	Cited By	Authors
1	Web Accessibility of Moocs For Elderly Students	2013	International Conference on Information Technology-Based Higher Education and Training, Ithet 2013	54	(Gordon & Mora, 2013)
2	Laan: Convergence of Knowledge Management and Technology-Enhanced Learning	2012	IEEE Transactions on Learning Technologies	38	(Chatti, Schroeder, & Jarke, 2012)
3	Supporting Learners' Self-Management for Self-Directed Language Learning: A Study Within Duolingo	2024	Interactive Technology and Smart Education	9	(Li, Bonk, & Zhou, 2024)
4	Outcomes-Based Assessment and Lessons Learned In Abet-Cac Accreditation: A Case Study Of The American University In The Emirates	2022	Mobile Information Systems	6	(Abualkishik et al., 2022)
5	User Behavior in Multi-Screen E-Learning	2015	Procedia Computer Science	6	(Kapenieks et al., 2015)
6	Piloting The Ebig3: A Triple-Screen E-Learning Approach	2014	CSEDU 2014 - Proceedings of The 6th International Conference on Computer Supported Education	5	(Kapenieks et al., 2014)
7	A Study of MOOCs Project (Mode It), Techniques, And Know How-Do How Best Practices and Lessons From The Pandemic Through The Tomorrow Age Theory	2023	Proceedings of 2022 IEEE Learning with MOOCs, LwMOOCs 2022	3	(Mohammadian, Langari, Castro, & Wittberg, 2022)
8	E-Ecosystem Driven E-Learning Vs Technology Driven E-Learning	2012	CSEDU 2012 - Proceedings of The 4th International Conference on Computer Supported Education	3	(Kapenieks, Zuga, Stale, & Jirgensons, 2012)
9	Learner Models for MOOC in A Lifelong Learning Context: A Systematic Literature Review	2021	Communications in Computer and Information Science	3	(Luelmo, El Mawas, & Heutte, 2021)
10	Seamless Integration of Knowledge Management and Professional Learning in Prime	2016	Communications in Computer and Information Science	0	(Chatti, Thüs, Greven, & Schroeder, 2016)

2025, ranked by total citations in Scopus to maintain methodological consistency. A total of 624 documents, comprising journal articles, conference papers, book chapters, and review studies, were analyzed to identify the most influential contributions shaping this domain. The top-cited publication, *"Web Accessibility of MOOCs for Elderly Students"* by (Gordon & Mora, 2013)has accumulated 54 citations, underscoring the growing scholarly attention to inclusive digital education, particularly for older learners. Ranked second is *"Laan: Convergence of Knowledge Management and Technology-Enhanced Learning"* by (Chatti et al., 2012), with 38 citations. This work exemplifies the lasting significance of integrating knowledge management principles into technology-enhanced learning frameworks.

Other notable examples include Li Z.'s (2024) study on self-directed language learning through Duolingo, which has already garnered nine citations within a short period, an early indicator of strong impact, and the growing emphasis on learner autonomy supported by digital tools. Similarly, research such as the ABET-CAC accreditation study by (Abualkishik et al., 2022) and the MOOC learner modeling work by Luelmo et al. (2021) demonstrate how digital pedagogy is evolving to address issues of quality assurance and personalization. Collectively, these contributions point to a pedagogical shift emphasizing resilience and innovation in response to global educational disruptions.

This combination of foundational, highly cited studies and newer, thematically relevant works suggests that the field is simultaneously consolidating its established knowledge base and expanding into emerging areas of inquiry. The variety of publication venues, ranging from IEEE Transactions on Learning Technologies and Mobile Information Systems to Interactive Technology and Smart Education, reflects the inherently interdisciplinary nature of this research landscape. Although post-2020 studies exhibit lower citation counts due to their recency, their focus on inclusivity, adaptive learning, and digital transformation signals the next phase of growth in digital education research. This pattern implies that while classic studies continue to anchor scholarly debates, newer works are redefining the research agenda toward inclusivity, digital equity, and adaptive pedagogies. For researchers, this means that citation impact is not only a measure of past influence but also an early indicator of which innovative themes are likely to shape future funding priorities and policy discussions.

Figure 6 illustrates the distribution of research output by the countries of corresponding authors, distinguishing between Single Country Publications (SCP) and Multiple Country Publications (MCP) from 2011 to 2025. This analysis, based on 624 Scopus-indexed documents, offers insight into national productivity and international collaboration in lifelong learning, technology, and e-learning research. China leads as the most prolific country, with an overwhelming majority of its contributions categorized as SCP. This pattern reflects China's strong domestic research ecosystem, supported by large-scale government funding and initiatives such as the Education Informatization 2.0 Action Plan, which prioritize national capacity building and technological self-reliance. The high SCP proportion also aligns with China's broader economic strategy of rapidly scaling digital infrastructure and producing policy-relevant research internally. India follows, also exhibiting a strong inclination toward domestically produced research. This is consistent with India's national programs such as Digital India and SWAYAM, which emphasize the development of scalable, locally driven solutions to meet the demands of its massive higher education sector. In both countries, strong domestic demand and policy

direction reduce reliance on international collaboration, thereby increasing SCP ratios.

These trends reflect concentrated national investment in educational technology research. Germany, Spain, and the United Kingdom complete the top five contributors, with more balanced SCP-to-MCP ratios. Figure 6. Distribution of research output by corresponding authors' countries, differentiating between Single Country Publications (SCP) and Multiple Country Publications (MCP) (2011–2025).

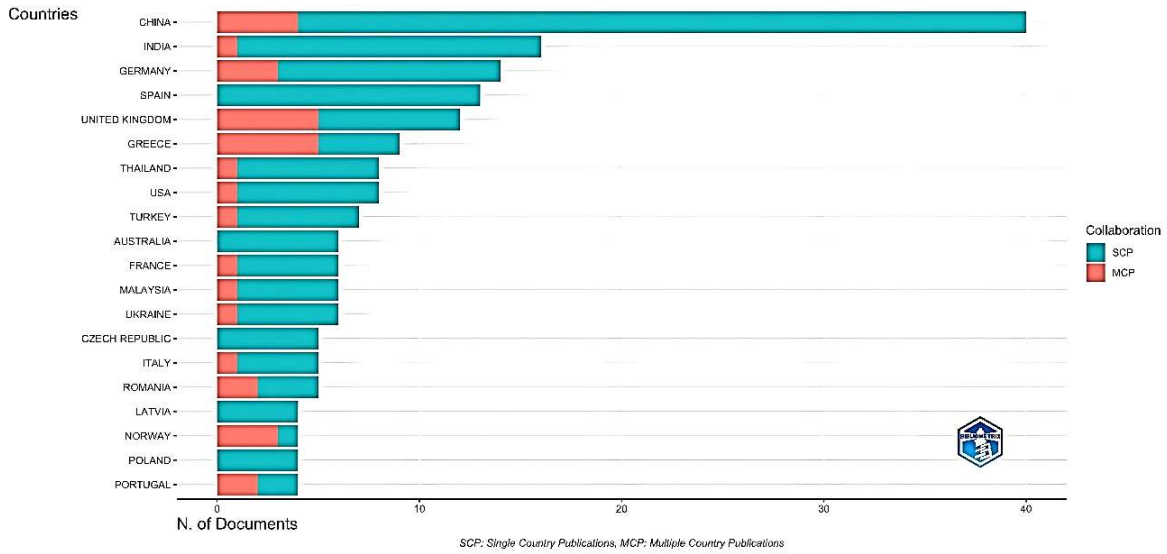

Figure 6. Geographical collaboration: single-country vs. multiple-country publications

The publication profiles of these countries reveal both substantial national output and strong participation in international research collaborations. Elevated MCP (Multiple Country Publication) ratios indicate policy frameworks and funding mechanisms that actively promote cross-border partnerships, particularly within the European Union's research schemes such as Horizon 2020 and Horizon Europe. This dual engagement reflects a mature and globally interconnected research environment. Beyond these leading contributors, countries such as Greece, Thailand, and the United States maintain moderate yet consistent levels of productivity and collaboration. Meanwhile, France, Malaysia, and Ukraine exhibit relatively higher MCP proportions, pointing to deliberate efforts to engage in cross-national research initiatives. Such collaborations enhance visibility, diversify perspectives, and foster knowledge exchange. Smaller European nations including the Czech Republic, Romania, Latvia, and Norway also demonstrate active participation in international networks despite lower publication volumes. Their emphasis on collaborative output reflects strategic attempts to integrate into global research ecosystems and strengthen institutional research capacity.

Overall, the comparative patterns between Asia and Europe suggest two distinct strategic orientations. Major Asian countries such as China and India prioritize domestic scalability and policy-driven self-sufficiency, while European nations emphasize integration and cooperative research models. This divergence underscores that educational technology research is influenced not only by scholarly priorities but also by broader geopolitical contexts, policy orientations, and funding infrastructures. For researchers, this implies that publication and collaboration

strategies should align with regional research ecosystems and leverage domestic programs and national agendas in Asia, while using cross-border funding mechanisms such as Horizon 2020 and Horizon Europe in Europe. For policymakers, these findings highlight the importance of balancing national capacity-building with international cooperation to sustain globally relevant and resilient research environments. Beyond national strategies, Table 2 highlights the main source titles that dominate the dissemination of research in this field.

Table 2. 10 most source titles that contribute to the publication on Lifelong Learning, Technology, and e-learning

Rank	Relevant sources	Document	Citation	Total link strength
1	ACM International Conference Proceeding Series	19	58	0
2	CEUR Workshop Proceedings	15	77	0
3	Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics	15	39	0
4	Communications in Computer and Information Science	10	34	0
5	Proceedings of the European Conference on e-learning, ECEL	9	14	0
6	British Journal of Educational Technology	8	254	0
7	Lecture Notes in Networks in Systems	8	12	178
8	Computer and Education	8	2	0
9	Sustainability (Switzerland)	7	156	0
10	Advances in Intelligent Systems and Computing	6	16	0

Table 2 summarizes the ten most prolific source titles contributing to scholarly publications in the fields of lifelong learning, technology, and e-learning from 2011 to 2025, based on a bibliometric analysis of 624 Scopus-indexed documents. The data captures both publication output and citation impact, providing a clear view of the intellectual centers within this interdisciplinary research landscape. The *ACM International Conference Proceedings Series* leads with 19 publications, underscoring its pivotal role in connecting educational research with advances in computing and technology. *CEUR Workshop Proceedings* and *Lecture Notes in Computer Science* (including its subseries in *Artificial Intelligence* and *Bioinformatics*) each contribute 15 documents, reaffirming their significance as outlets for disseminating applied and technical studies in digital education.

Among academic journals, the *British Journal of Educational Technology* stands out for its influence and scholarly prestige. Although it accounts for only eight publications, these works have collectively received 254 citations, the highest total among all listed sources, highlighting the journal's impact within the field of educational technology. Similarly, *Sustainability (Switzerland)* demonstrates a strong citation record, with 156 citations across seven publications, reflecting increasing scholarly attention to the environmental and long-term sustainability dimensions of digital learning

ecosystems. *Lecture Notes in Networks and Systems* also shows notable influence, with a total link strength of 178, indicating that its papers occupy central positions within co-authorship and thematic clustering networks, despite modest publication and citation counts.

Other contributors, including Communications in Computer and Information Science, the Proceedings of the European Conference on E-Learning (ECEL), and Computers & Education, provide a steady stream of scholarly output that spans educational policy, instructional design, and assessment practices, representing diverse perspectives. Collectively, these publication venues illustrate the field's technological orientation and interdisciplinary scope. The breadth of outlets across engineering, computer science, educational theory, and sustainability underscores the multifaceted, integrative approach required to advance research on lifelong learning and e-learning.

Figure 7 presents a bibliographic coupling map of intellectual linkages among countries based on shared references in publications on lifelong learning, technology, and e-learning from 2011 to 2025. Drawn from 624 Scopus-indexed records, the map reveals patterns of collaboration and thematic convergence among nations actively contributing to this body of research. Several distinct country clusters are evident, each representing regional and thematic cohesion.

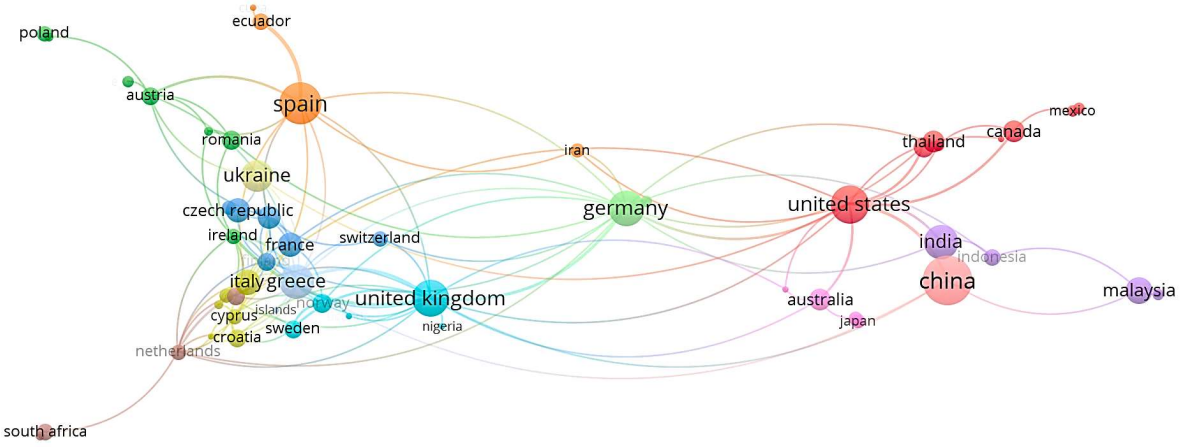

Figure 7. Bibliographic coupling map of countries

A dominant red cluster encompasses the United States, China, India, and Thailand, indicating dense mutual referencing and a shared focus on digital innovation and educational reform. These countries occupy central positions in the global scholarly network, serving as key drivers in shaping international discourse on technology-enhanced learning. Germany, Spain, and Iran anchor the green cluster. Germany's central positioning and numerous bibliographic links underscore its role as an integrative hub within the international research landscape. Spain maintains strong ties with Latin American and Eastern European countries, such as Ecuador, Romania, and Ukraine, reflecting linguistic and regional affinities. The blue cluster, led by the United Kingdom, Italy, and Greece, includes several Nordic and Central European countries. This group reflects tight intra-European collaboration and emphasizes structured, policy-driven approaches to lifelong learning. The UK's dense interconnectivity suggests a leadership role in developing research frameworks and thematic discourse.

Smaller clusters, notably those represented in purple and pink, comprise countries such as

Malaysia, Indonesia, and Australia. Although these regions exhibit fewer overall linkages, their growing participation in collaborative networks indicates a growing role in shaping digital education discourse, particularly in the Asia-Pacific context.

Dominant and Foundational Research Themes

Figure 8 displays a keyword tree map generated from 624 Scopus-indexed documents, offering a visual summary of the thematic distribution in lifelong learning, technology, and e-learning research from 2011 to 2025. Each block represents the frequency and relative emphasis of keywords used by authors, providing insight into prevailing research priorities and emerging trends.

The most frequently occurring term is *"lifelong learning,"* which appears 127 times (22%), underscoring its central role across the literature. This is followed closely by *"e-*

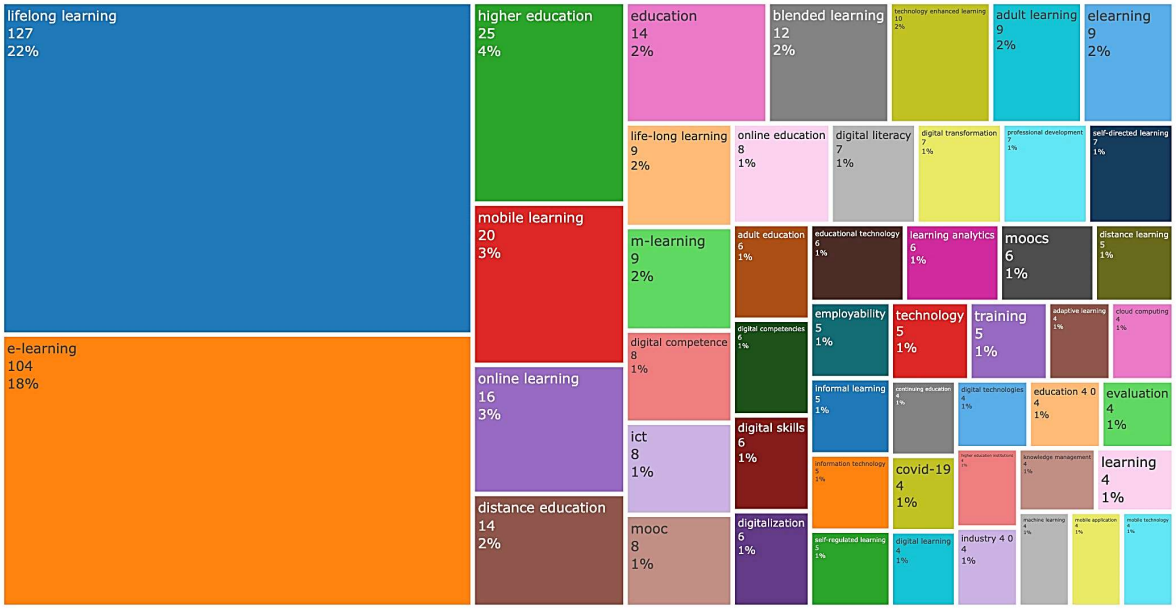

Figure 8. Tree map of authors' keywords

learning" with 104 instances (18%), reflecting the widespread adoption of digital tools in education and the global movement toward online learning environments. Secondary clusters such as *"higher education"* (25), *"mobile learning"* (20), and *"online learning"* (16) highlight the increasing focus on flexible, technology-mediated, and institution-based learning modes. Meanwhile, terms such as "distance education" (14), "blended learning" (12), and "online education" (8) further underscore the diversification of delivery models in the digital education landscape. Keywords including *"adult learning," "self-directed learning,"* and *"informal learning"* suggest a sustained pedagogical emphasis on learner autonomy and lifelong skill development beyond formal education settings. Likewise, frequent references to *"digital literacy," "digital competence," "ICT,"* and *"digital skills"* indicate heightened attention to issues of digital readiness and equity. Emerging and topical terms such as *"COVID-19," "digital transformation,"* and *"Industry 4.0"* illustrate how global disruptions and technological shifts have reshaped research priorities.

Applied, practice-oriented keywords such as "MOOC," "learning analytics," "employability," and "training" reveal the growing intersection of technology integration, workforce

development, and social inclusion. Collectively, these trends suggest that research on lifelong learning and e-learning is increasingly addressing not only pedagogical and technological advancements but also their broader implications for labor-market adaptation and social equity. For researchers, this underscores the importance of aligning keyword-level analyses with larger societal concerns, ensuring that future studies engage with themes of employability, inclusivity, and sustainability in digital education.

These patterns affirm that lifelong learning and e-learning function not merely as pedagogical constructs but as socio-technical responses to global transformation. As noted by Mungra et al. (2024), the prominence of keywords related to *digital competence* and *digital transformation* reflects a field-wide pivot toward equity, employability, and readiness for Education 4.0. The tree map visualization highlights how foundational concepts such as *lifelong learning* are increasingly interlinked with contemporary pressures, including digital equity and workforce resilience. While Figure 8 illustrates the relative frequency of these keywords, Figure 9 presents a co-occurrence network that visualizes

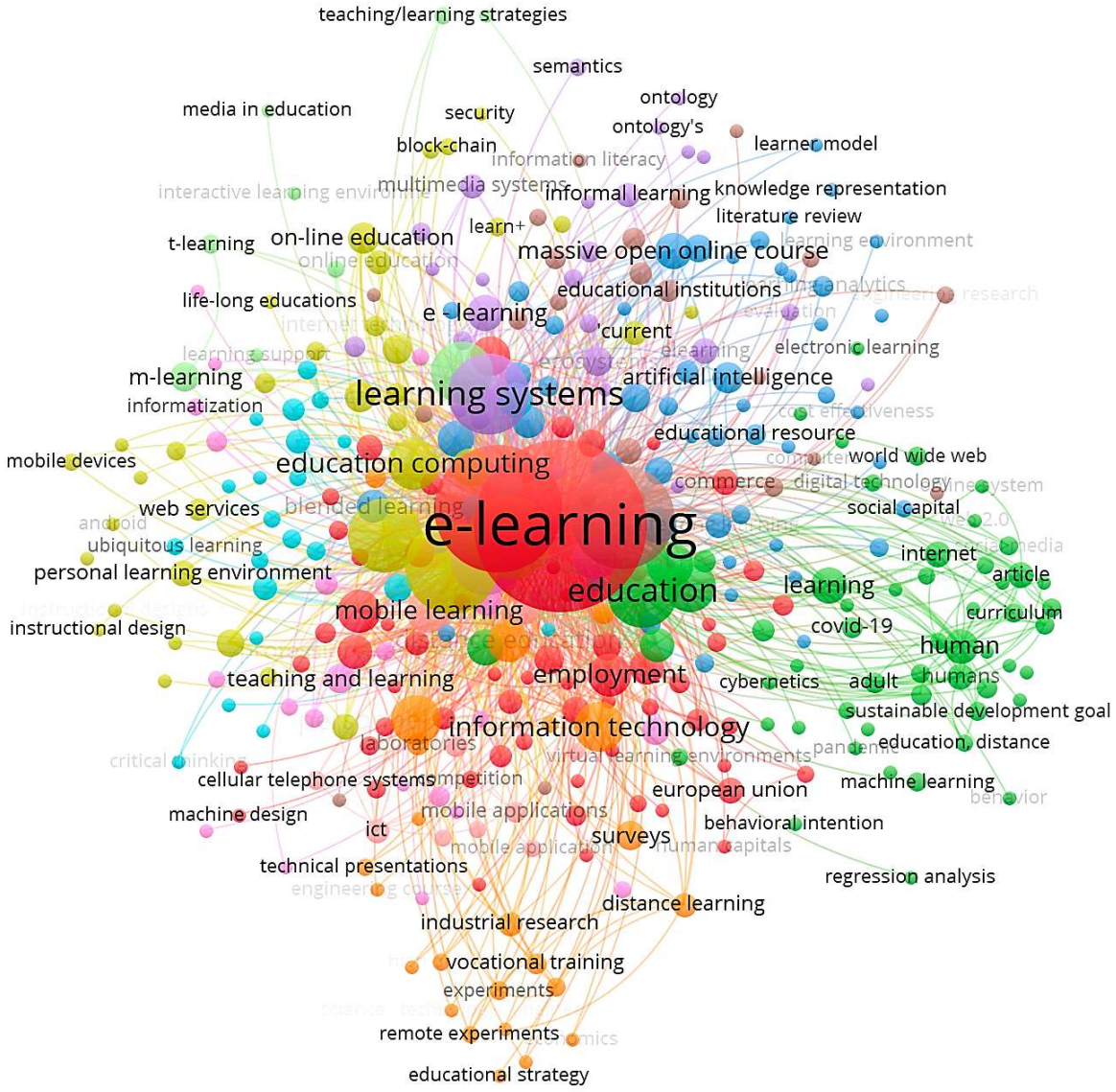

Figure 9. Network visualization of keyword co-occurrence in lifelong learning, technology, and e-learning research (2011–2025)

how key terms cluster and interconnect, revealing the field's structural and thematic architecture.

Figure 9 maps the keyword co-occurrence network generated from 624 Scopus-indexed publications spanning 2011 to 2025. This visualization exposes the relationships between core and peripheral terms, offering insights into the conceptual organization and evolving thematic directions that that the interdisciplinary landscape of lifelong learning, technology, and e-learning research.

At the core of the network lies *"e-learning,"* the most frequently co-occurring keyword, underscoring its central role in shaping the broader research landscape. Closely connected nodes such as *"education," "learning systems," "educational computing,"* and *"mobile learning"* collectively reflect the digital infrastructure, platform integration, and pedagogical frameworks that underpin modern technology-enhanced learning environments. Thematic clusters are distinctly color-coded. The blue cluster encompasses system-oriented components, including *"learning systems," "online education," "instructional design,"* and *"teaching and learning."* These keywords highlight a strong focus on the technical and instructional architecture that underpins digital education environments. In contrast, the red cluster centers on socioeconomic dimensions, represented by terms such as *"information technology," "employment," "vocational training,"* and *"surveys."* The associations within this cluster indicate ongoing interest in how digital education influences workforce preparedness and social integration, underscoring the role of lifelong learning in driving economic and human capital development.

The green cluster highlights themes of learner diversity and digital inclusion. Keywords such as *"human," "digital literacy," "curriculum,"* and *"adult"* point to a human-centered orientation in e-learning research that emphasizes access, equity, and the design of personalized learning pathways. Peripheral yet emerging topics, including "massive open online courses (MOOCs)," "artificial intelligence," "COVID-19," and "cybernetics," reflect recent global and technological disruptions that have accelerated pedagogical and technological innovation in the field. Interdisciplinary linkages are also evident in terms such as *"blockchain," "semantics,"* and *"ontology,"* revealing intersections between educational inquiry and advances in computing and information science. The presence of these terms indicates that the field is moving toward deeper integration with cutting-edge technologies, which opens opportunities for innovative methodological frameworks. For scholars, this implies that future work should go beyond mapping keyword networks to interrogate how these intersections can generate new models of digital pedagogy and policy relevance.

For researchers, the co-occurrence map suggests two key directions: (1) reinforcing established debates around core clusters such as teaching, education, and vocational training, and (2) advancing emerging intersections between e-learning and technologies like AI, blockchain, and learning analytics. As noted by Gouws & Kritzinger (2023), the convergence of workforce-oriented and equity-focused keywords illustrates how digital education research increasingly serves as a bridge between societal change and economic transformation.

Dominant Research Themes and Conceptual Structures

Figure 10 illustrates the temporal evolution of emerging research themes in lifelong learning, technology, and e-learning, derived from a term frequency analysis of 624 Scopus-indexed publications covering the period 2011–2025. This timeline visualization reveals how scholarly priorities have evolved, reflecting both the field's conceptual maturation and its adaptive response to technological progress and societal transformation.

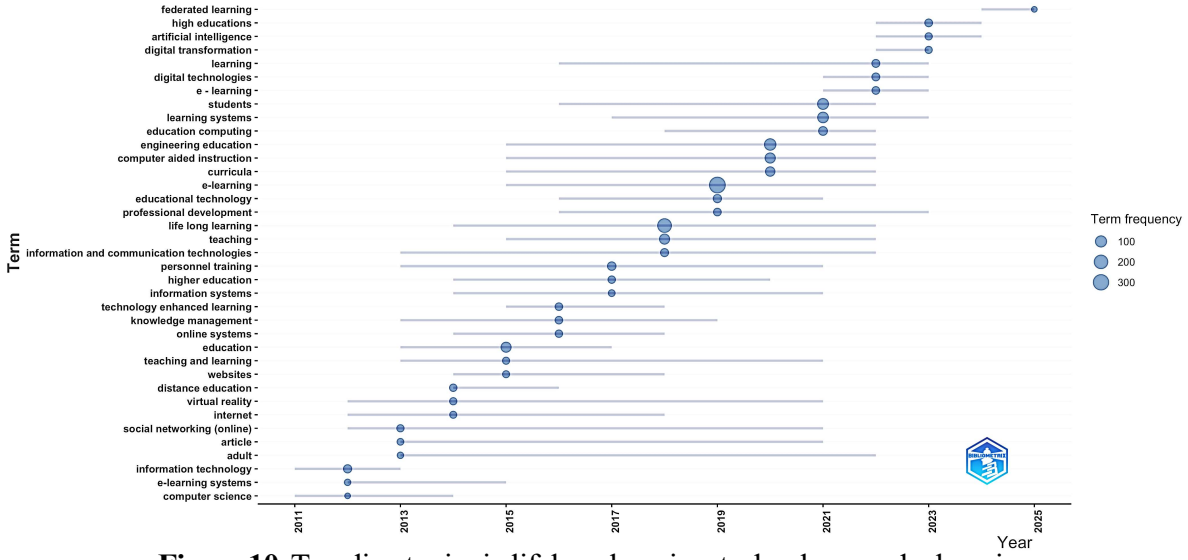

Figure 10. Trending topics in lifelong learning, technology, and e-learning

In the early phase (2011–2014), research centered on foundational concepts such as "computer science," "information technology," "internet," and "virtual reality." These terms signal an emphasis on infrastructure development and digital access as foundational components of online education. Terms such as *"adult," "distance education,"* and *"websites"* also appeared during this period, reflecting initial attempts to expand educational access and adapt traditional learning models to emerging digital contexts.

Starting around 2015, the literature began to incorporate more pedagogically oriented and system-level innovations. Keywords such as *"teaching and learning," "educational technology," "students," "e-learning,"* and *"learning systems"* gained prominence during this phase. This trend reflects a deepening scholarly interest in digital instructional design, learner engagement, and the development of technological platforms that support scalable, flexible education. From 2018 through 2023, the discourse expanded to include practice-oriented and interdisciplinary topics. Key terms such as "technology-enhanced learning," "professional development," "digital technologies," and "education computing" reflect applied strategies for advancing digital pedagogy. At the same time, the emergence of terms such as *"learning analytics," "knowledge management,"* and *"information systems"* indicates a growing scholarly focus on data-driven and adaptive learning environments.

In the most recent phase (2023–2025), new research frontiers have emerged. Keywords such as *"federated learning," "artificial intelligence," "digital transformation,"* and *"higher education"* reflect the growing integration of AI and distributed computing within educational contexts. These developments signal the field's transition toward intelligent, personalized, and institutionally embedded learning solutions. This trajectory indicates that scholarship is evolving from descriptive or infrastructure-oriented studies toward adaptive, data-driven models capable of addressing systemic educational challenges.

As observed by Vonitsanos et al. (2024), the adoption of AI and data analytics represents not only a methodological advancement but also a strategic response to the demand for scalable, personalized lifelong learning. For researchers, this shift underscores the need to evaluate both

outcomes and equity within these advanced systems, ensuring that technological innovation translates into tangible benefits for diverse learner populations. While Figure 10 illustrates the temporal dynamics of keyword evolution, Figure 11 extends the analysis by mapping the conceptual structures underlying thematic transformations.

This evolution reveals three intertwined dynamics. Continuity is evident as *"e-learning"* remains a persistent theme across all periods. Transformation is reflected in the shift from infrastructure and access to pedagogy and interdisciplinary applications. Emergence and decline characterize the rise of new topics such as *AI, IoT,* and *MOOCs*, alongside the fading relevance of earlier themes such as *social networking* and *digital devices.* As Mungra et al. (2024) note, these transitions exemplify how digital education research adapts to global challenges and technological disruptions. For scholars, tracing these thematic shifts offers valuable insight into how academic contributions can both anticipate and shape the field's future trajectory.

Figure 11 presents a thematic map outlining the conceptual structure of research on lifelong learning, technology, and e-learning between 2011 and 2025. Using centrality (relevance) and density (development) as analytical axes, the map derived from 624 Scopus-indexed publications categorizes themes into four quadrants: *Motor Themes, Basic Themes, Niche Themes,* and *Emerging or Declining Themes*. This framework provides a concise representation of the maturity, significance, and developmental trajectory of major research topics in the field.

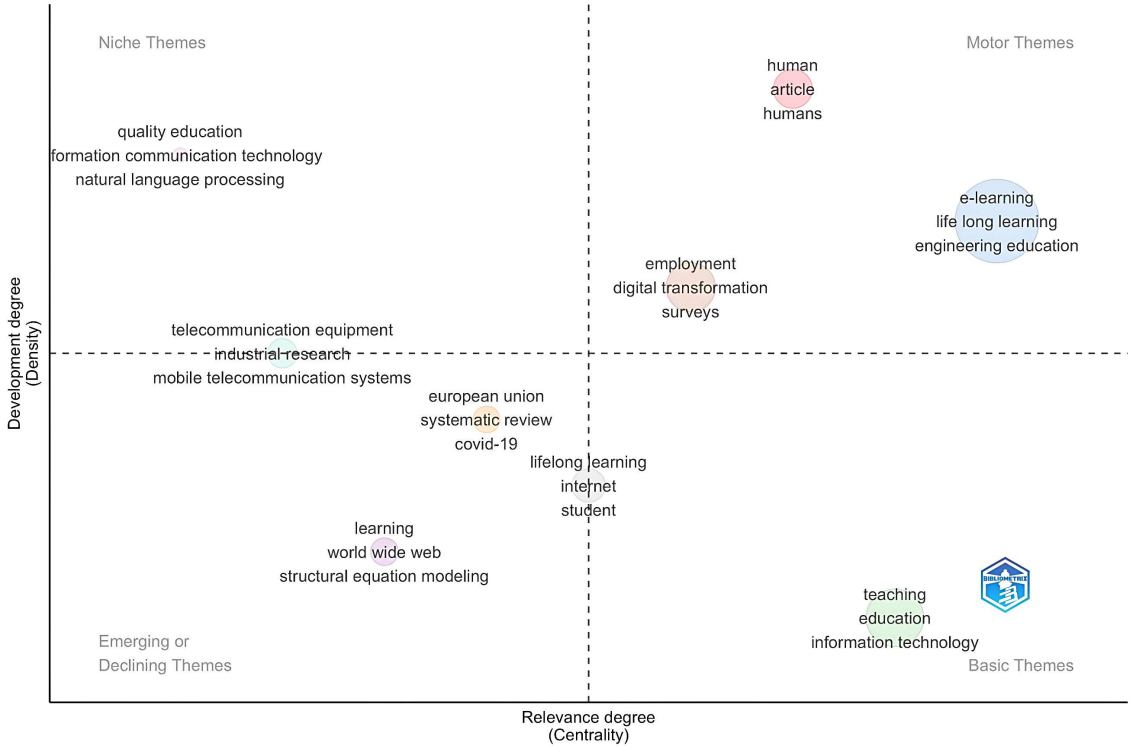

Figure 11. Thematic map of lifelong learning, technology, and e-learning

The upper-right quadrant, labeled Motor Themes, includes "e-learning," "lifelong learning," and "engineering education." These terms exhibit high centrality and density, indicating that they are both highly connected and well-developed. Their positioning indicates that these themes constitute

the intellectual and practical core of the field, driving both innovation and policy development in digital pedagogy and vocational learning. For researchers, this suggests that engaging with these areas offers opportunities to contribute to highly visible, policy-relevant scholarship. However, it also demands advancing the discourse through fresh conceptual and methodological insights rather than revisiting established conclusions. In the lower-right quadrant, representing Basic Themes, keywords such as *"teaching," "education,"* and *"information technology"* appear. These concepts remain fundamental to the field but exhibit lower density, suggesting that while they function as structural anchors, they lack deep internal specialization. They underpin a wide range of studies and continue to inform more targeted developments within digital learning research. For scholars, this implies that although these areas remain vital entry points, the research potential lies in re-contextualizing them, for instance, by linking traditional teaching practices with digital innovation or embedding information technology frameworks within lifelong learning agendas.

The upper-left quadrant features Niche Themes, including *"quality education," "natural language processing,"* and *"information and communication technology."* These topics exhibit advanced internal development but limited external relevance, suggesting specialization within narrower subfields or emerging technical areas. Their presence highlights opportunities for focused scholarly contributions and the need to bridge niche innovations with broader educational concerns, ensuring that technical progress translates into meaningful pedagogical and social impact. The lower-left quadrant encompasses Emerging or Declining Themes. Keywords such as *"learning," "structural equation modeling,"* and *"World Wide Web"* fall within this category, suggesting either waning scholarly interest or early-stage conceptual growth. Other terms, such as "COVID-19," "systematic review," and "European Union," occupy positions near the center of the map, reflecting temporary yet notable influence during specific global or contextual shifts in education. Interestingly, broadly framed terms such as *"lifelong learning," "student,"* and *"internet"* appear close to the origin, indicating their wide applicability but limited recent thematic refinement. These observations align with Gouws & Kritzinger (2023) who argue that the responsiveness of themes such as *COVID-19* illustrates how external disruptions can redirect scholarly focus and reshape research agendas. For future work, refining broad yet underdeveloped categories such as "student" or "internet" may yield valuable insights into lifelong learning in digital contexts, particularly when examined through the lenses of equity, digital competence, and emerging educational technologies.

Evolution and Transformation of Research Themes

Figure 12 illustrates a thematic evolution map tracing the progression of major research concepts in lifelong learning, technology, and e-learning across four distinct periods: 2011–2014, 2015–2018, 2019–2022, and 2023–2025. Drawing on 624 Scopus-indexed publications, the Sankey-style visualization captures how central themes have emerged, evolved, and interconnected over time, reflecting the field's conceptual continuity and transformation.

During the initial phase (2011–2014), "e-learning" emerged as the dominant theme, accompanied by foundational terms such as "education," "mobile learning," "human," and "social networking (online)." These keywords reflect early research interests in digitizing traditional education models, exploring learner engagement, and understanding the role of

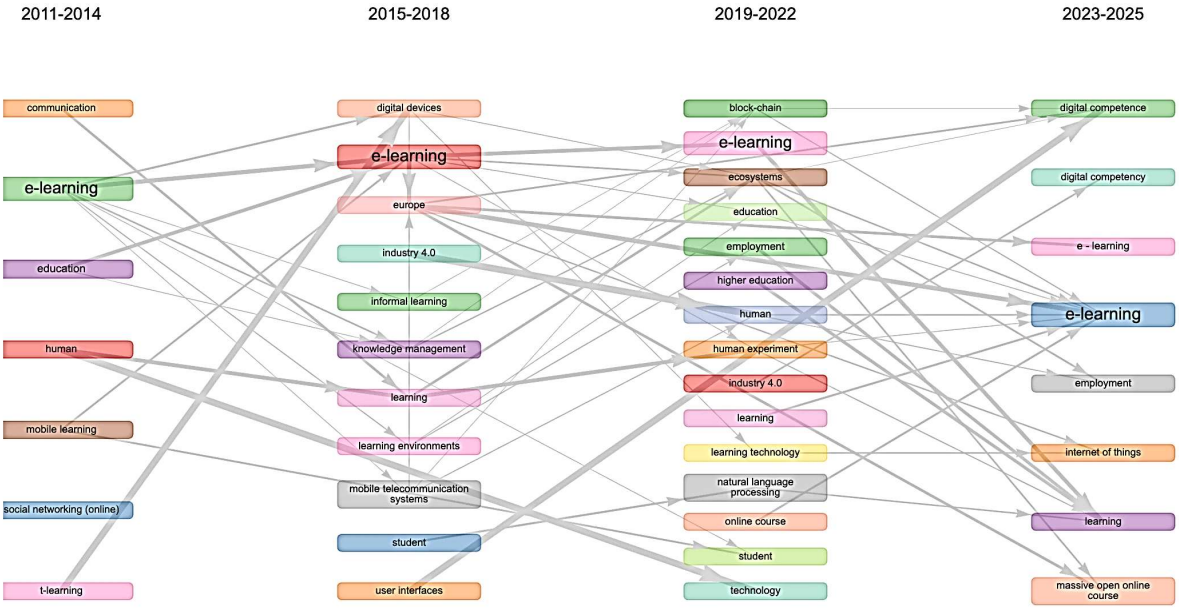

Figure 12. Thematic evolution of lifelong learning, technology, and e-learning

technology in expanding educational access. This shows that the early period was largely exploratory, focused on testing the feasibility of digital modalities. In the 2015–2018 period, the research landscape diversified. While "e-learning" remained central, it became connected to more specialized themes, including "digital devices," "knowledge management," and "industry 4.0," reflecting the influence of industrial and technological paradigms on educational discourse. The inclusion of "informal learning," "learning environments," and "user interfaces" points to an increased focus on non-formal education settings and user-centered design principles. This indicates a shift from infrastructure-focused studies to pedagogically oriented, user-centered innovations.

Between 2019 and 2022, the field's thematic structure showed clear signs of maturation. *"E-learning"* remained the dominant focus but became increasingly intertwined with advanced concepts such as *"blockchain," "ecosystems," "natural language processing,"* and *"learning technology."* The emergence of terms such as "higher education," "employment," and "human experiment" points to a shift toward more empirical, outcomes-oriented research that addresses the practical applications of digital learning systems. Meanwhile, earlier focal areas such as *"social networking"* and *"digital devices"* showed a marked decline in prominence. This period reflects a transition from exploratory experimentation with digital tools to impact-driven, system-level inquiry. The trend aligns with Wang's (2024) observations, which highlight the growing demand for scalability, accountability, and measurable outcomes in lifelong learning initiatives.

In the most recent phase (2023–2025), *"e-learning"* remains a central focus, while emerging themes such as *"digital competence," "digital competency,"* and the *"Internet of Things (IoT)"* highlight the continued evolution of learner skill development and system-level integration. The resurgence of *"massive open online courses (MOOCs)"* points to renewed scholarly and institutional interest in scalable, accessible education models, particularly amid global transitions and the ongoing expansion of lifelong

learning infrastructures. The reappearance of MOOCs illustrates how certain research themes can regain relevance when external conditions, such as post-pandemic recovery and digital equity policies, create new opportunities for scale and inclusion. This cyclical pattern underscores the adaptability of research priorities to shifting global contexts, aligning with Marouan et al. (2024), who emphasize that the field's evolution is deeply intertwined with broader technological and social transformations.

Overall, the thematic evolution reveals three interconnected dynamics. First, continuity: "e-learning" remains a stable core theme across all periods. Second, transformation, as early emphases on infrastructure and access have gradually given way to more sophisticated, data-driven, and interdisciplinary approaches. Third, emergence and decline, marked by the rise of new themes such as *AI, IoT,* and *digital competence*, alongside the diminishing prominence of earlier topics, such as *social networking*. For researchers, these patterns highlight the value of examining not only which topics dominate at a given point in time but also how themes evolve, recede, or reappear. Such longitudinal awareness enables scholars to anticipate emerging frontiers and position their work within the broader intellectual trajectory of lifelong learning and digital education research.

Overall, this bibliometric analysis not only charts the structural landscape of research on lifelong learning, technology, and e-learning but also highlights avenues for advancing the field. The findings emphasize the need for sustained cross-disciplinary collaboration, strategic investment in emerging technologies, and inclusive frameworks that expand equitable access to lifelong learning opportunities (Skvarc & Markulin, 2024). Future studies should move beyond descriptive mapping to engage in longitudinal evaluations of learning outcomes, focusing not only on research productivity but also on the pedagogical, institutional, and societal impacts of digital education (Gouws & Kritzinger, 2023; Vonitsanos et al., 2024). Promising directions include the integration of AI tutors, blockchain-based learning credentials, and digital twin environments, which may transform the way learning is personalized, verified, and simulated (Marouan, Badrani, Kannouf, & Chetouani, 2024; Sarshartehrani, Mohammadrezaei, Behravan, & Gracanin, 2024; X. Wang, 2025). Equally, studies on semantic ontologies and digital infrastructures highlight the importance of developing adaptive and intelligent learning frameworks (Bulathwela et al., 2024; Hodroj, Lamolle, & Sabeima, 2023). Expanding bibliometric inquiries to include non-English literature and open-access platforms will also capture a more representative global perspective. By engaging with these areas, future scholarship can reinforce both the theoretical foundations and practical implementations of digital lifelong learning, fostering education systems that are more resilient, equitable, and sustainable worldwide.

■ CONCLUSION

This bibliometric study offers a comprehensive synthesis of the evolution, structural dynamics, and thematic trajectories of research on lifelong learning, technology, and e-learning from 2011 to 2025. The findings reveal a rapidly expanding field that has responded decisively to global disruptions, most notably the COVID-19 pandemic, which served as a powerful catalyst for digital transformation across education systems worldwide. The marked increase in publication activity after 2020 reflects the academic community's concerted effort to confront emerging educational challenges through digital innovation and technology-mediated learning. The prominence of scholarly contributions from key platforms, such as the ACM International Conference Proceedings and

the CEUR Workshop Proceedings, and from high-impact journals, such as the British Journal of Educational Technology and Sustainability, confirms the interdisciplinary and practice-oriented nature of this research domain. Influential scholars, including Li Z., Castro M., and El Mawas N., and major contributing nations such as China, India, and Germany, illustrate the global reach and collaborative essence of digital education research.

The thematic analysis identified *"e-learning," "lifelong learning,"* and *"digital competence"* as enduring core constructs, while also highlighting forward-looking areas such as *artificial intelligence (AI), MOOCs,* and *digital transformation.* These emerging themes signal a paradigm shift toward technologically integrated, learner-centered, and equity-oriented educational frameworks. The primary contribution of this study lies in its comprehensive mapping of the field's intellectual and thematic landscape. For researchers, this synthesis exposes specific thematic gaps and emerging frontiers that warrant exploration through innovative methodologies. For educators and policymakers, it offers evidence-based insights to inform investments in digital infrastructure, the design of inclusive pedagogical models, and the advancement of sustainable lifelong learning initiatives. By identifying influential authors, key sources, thematic clusters, and patterns of collaboration, this research provides strategic direction for strengthening scholarly engagement, pedagogical innovation, and educational policy development. Future work should expand upon these findings by incorporating multilingual and regionally diverse datasets, examining the pedagogical implications of advanced technologies, and adopting longitudinal approaches to evaluate sustained educational outcomes. Such efforts will be critical for ensuring that lifelong learning systems remain relevant, inclusive, and resilient in an increasingly digital and interconnected world.

Nevertheless, this study is not without limitations. First, the analysis relied exclusively on the Scopus database, which, while comprehensive, may exclude relevant works indexed by other services or published in non-English outlets, potentially limiting global representativeness. Second, the 2025 dataset is incomplete because data collection was conducted in July 2025, which may underrepresent recent publication trends. Third, the search query was restricted to the keywords *"lifelong learning," "technology,"* and *"e-learning."* While these terms effectively capture the field's central intersection, they may omit adjacent yet equally significant themes, such as *digital pedagogy* or *open educational resources.* Future research should broaden database coverage, include multilingual sources, and refine keyword strategies to encompass a wider conceptual spectrum and promote greater inclusivity in scholarly representation.

In conclusion, by mapping influential authors, key sources, thematic clusters, and patterns of collaboration, this study offers strategic insights to advance scholarly inquiry, foster instructional innovation, and inform evidence-based educational policy. Future research should build on these findings by examining the pedagogical implications of emerging technologies, adopting longitudinal approaches to evaluate long-term learning outcomes, and incorporating a broader range of regional and linguistic perspectives. Such efforts are essential to sustain the relevance, inclusivity, and resilience of lifelong learning systems in an increasingly digital and interconnected world.

■ REFERENCES

Abualkishik, A. , Z., Atassi, R., Singh, A., Elhoseny, M., Alwan, A. A., Iqbal, R., & Khelifi, A. (2022). Outcomes-Based assessment and lessons learned in ABET-CAC accreditation: a case study of the

american university in the emirates. *Mobile Information Systems*, *2022*. doi:10.1155/2022/1595126

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975. doi:https://doi.org/10.1016/j.joi.2017.08.007

Aria, M., Cuccurullo, C., D'Aniello, Misuraca, M., & Spano, M. (2024). Comparative science mapping: a novel conceptual structure analysis with metadata. *Scientometrics*, 129, 7055–7081. doi:https://doi.org/10.1007/s11192-024-05161-6

Blank, U., & Schmidt, I. (2022). Assessing digital self-efficacy: Review and scale development. *Computers and Education*, 191. doi:10.1016/j.compedu.2022.104626

Bulathwela, S., Pérez-Ortiz, M., Holloway, C., Cukurova, M., & Shawe-Taylor, J. (2024). Artificial intelligence alone will not democratise education: on educational inequality, techno-solutionism and inclusive tools. *Sustainability* (Switzerland), 16(2). doi:10.3390/su16020781

Chatti, M. A., Schroeder, U., & Jarke, M. (2012). LaaN: Convergence of knowledge management and technology-enhanced learning. *IEEE Transactions on Learning Technologies*, 5(2), 177–189. doi:10.1109/TLT.2011.33

Chatti, M. A., Thüs, H., Greven, C., & Schroeder, U. (2016). Seamless integration of knowledge management and professional learning in PRiME. In J. Uhomoibhi, M. T. Restivo, S. Zvacek, & M. Helfert (Eds.), *Communications in Computer and Information Science*, 583, 541–557. Springer Verlag. doi:10.1007/978-3-319-29585-5_31

Gordon, S., & Mora, S. , L. (2013). Web accessibility of MOOCs for elderly students. In 2013, the 12th International Conference on Information Technology-Based Higher Education and Training (ITHET 2013). *IEEE Computer Society*. doi:10.1109/ITHET.2013.6671024

Gouws, P., & Kritzinger, E. (2023). Using massive open online courses (MOOCs) to create learning spaces for quality lifelong learning for all communities through engaged scholarship (ES). In H. Y.-M. & T. Rocha (Eds.), *Lecture Notes in Computer Science* (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) (Vol. 14099 LNCS, pp. 345–355). Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-40113-8_34

Hodroj, S., Lamolle, M., & Sabeima, M. (2023). A multimedia resource ontology for semantic e-learning domain. In A. Rocha, C. Ferrás, & W. Ibarra (Eds.), *Lecture Notes in Networks and Systems* (Vol. 691 LNNS, pp. 551–560). Springer science and business media deutschland GmbH. doi:10.1007/978-3-031-33258-6_50

Jhanwar, K. Y., & Sadaria, P. (2025). From pen to pixel: understanding learning shifts with student insights in E-Education. In S. Rajagopal, K. Popat, D. Meva, S. Bajeja, & P. Mudholkar (Eds.), *Communications in Computer and Information Science* (Vol. 2426 CCIS, pp. 326–338). Springer science and business media deutschland GmbH. doi:10.1007/978-3-031-86296-0_23

Kapenieks, A., Zuga, B., Gorbunovs, A., Jirgensons, M., Kapenieks, J., Vitolina, I., … Balode, A. (2015). User behavior in multi-screen elearning. In de A. M. S, E. Theodotou, E. Theodotou, V. Snasel, Y. Saleh, S. A.-B., … S. Kumar (Eds.), *Procedia Computer Science*, 65, 761–

767. Elsevier. doi:10.1016/j.procs.2015.09.021

Kapenieks, A., Zuga, B., Stale, G., & Jirgensons, M. (2012). e-Ecosystem driven e-learning vs technology driven e-learning. In CSEDU 2012 - Proceedings of the 4th *International Conference on Computer Supported Education*, 2, 436–439. SciTePress. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-84864879507&partnerID=40&md5=22fa08f26b3f0e4642a2459cc854afb5

Kapenieks, A., Zuga, B., Vitolina, I., Kapeniks Jr., J., Gorbunovs, A., Jirgensons, M., … Balode, A. (2014). Piloting the eBig3: A triple-screen e-learning approach. In CSEDU 2014 - *Proceedings of the 6th International Conference on Computer Supported Education*, 1, 325–329. SciTePress. doi:10.5220/0004848603250329

Kapoor, G., Chahal, A., Sharma, N., Kaur, S., & Hendrik, H. (2025). Electronic-learning: Friend or Foe. *International Journal of Educational Reform*, 34(2), 405–415. doi:10.1177/10567879221140095

Kummanee, J., Nilsook, P., Piriyasurawong, P., & Wannapiroon, P. (2023). Digital learning ecosystem based on the steam gamification concept to develop innovator characteristics of vocational learners. In M. E. Auer, W. Pachatz, & T. Rüütmann (Eds.), *Lecture Notes in Networks and Systems*, 634 LNNS, 695–706. Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-26190-9_73

Li, Z., Bonk, C. J., & Zhou, C. (2024). Supporting learners' self-management for self-directed language learning: a study within Duolingo. *Interactive Technology and Smart Education*, 21(3), 381–402. doi:10.1108/ITSE-05-2023-0093

Luelmo, S. , I. , R., El Mawas, N., & Heutte, J. (2021). Learner models for MOOC in a lifelong learning context: a systematic literature review. In H. C. Lane, S. Zvacek, & J. Uhomoibhi (Eds.), *Communications in Computer and Information Science*, 1473, 392–415. Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-030-86439-2_20

Marouan, A., Badrani, M., Kannouf, N., & Chetouani, A. (2024). Empowering education: leveraging blockchain for secure credentials and lifelong learning. In *Signals and Communication Technology*, F2283, 1–14. Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-49593-9_1

Mohammadian, H. D., Langari, Z. G., Castro, M., & Wittberg, V. (2022). A study of MOOCs Project (MODE IT), techniques, and know how-do how best practices and lessons from the pandemic through the tomorrow age theory. In *Proceedings of 2022 IEEE Learning with MOOCS*, LWMOOCS 2022 (pp. 179–191). Institute of Electrical and Electronics Engineers Inc. doi:10.1109/LWMOOCS53067.2022.9927790

Mungra, Y., Srivastava, R., Sharma, A., Banerji, D., & Gollapudi, N. (2024). Impact of digital competence on employees' flourishing through basic psychological needs satisfaction. *Journal of Computer Information Systems*, 64(1), 47–61. doi:10.1080/08874417.2023.2176948

Sarshartehrani, F., Mohammadrezaei, E., Behravan, M., & Gracanin, D. (2024). Enhancing e-learning experience through embodied ai tutors in immersive virtual environments: a multifaceted approach for personalized educational adaptation. In R. A. Sottilare & J. Schwarz (Eds.), *Lecture Notes in Computer Science* (including subseries Lecture Notes in

Artificial Intelligence and Lecture Notes in Bioinformatics) (Vol. 14727 LNCS, pp. 272–287). Springer science and business media deutschland GmbH. doi:10.1007/978-3-031-60609-0_20

Savchenko, M., Synytsya, K., & Synyakova, S. (2023). Recommendation methods for information technology support of lifelong learning situations. In *Lecture Notes on Data Engineering and Communications Technologies* (Vol. 178, pp. 552–564). Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-35467-0_33

Segura, R. I., Garrido, Y. C., Morueta, R. T., & Miranda, F. P. R. (2023). Adapting digital competence 2.1 from the DigCom Model in the context of active ageing. In F. Moreira, C. S. Gonzalez-Gonzalez, A. Infante-Moro, J. C. Infante-Moro, J. Gallardo-Perez, A. Garcia-Holgado, & F. J. Garcia-Penalvo (Eds.), *Proceedings - JICV 2023: 13th International Conference on Virtual Campus*. Institute of Electrical and Electronics Engineers Inc. doi:10.1109/JICV59748.2023.10565720

Skvarc, G., & Markulin, T. (2024). Assessing the impact of large-scale ICT investment in education through measuring the digital maturity of schools. In T. Volariæ, B. Crnokiæ, & D. Vasiæ (Eds.), *Communications in Computer and Information Science*, 2124 CCIS, 84–96. Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-62058-4_7

Stefan, I., Barkoczi, N., Todorov, T., Peev, I., Pop, L., Marian, C., … Morales, L. (2023). Technology and education as drivers of the fourth industrial revolution through the lens of the new science of learning. In P. Zaphiris, A. Ioannou, & A. Ioannou (Eds.), *Lecture Notes in Computer Science* (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) (Vol. 14040 LNCS, pp. 133–148). Springer Science and Business Media Deutschland GmbH. doi:10.1007/978-3-031-34411-4_11

Vonitsanos, G., Moustaka, I., Doukakis, S., & Mylonas, P. (2024). Transforming education in the digital age: exploring the dimensions of education 4.0. In IEEE Global Engineering Education Conference, EDUCON. *IEEE Computer Society*. doi:10.1109/EDUCON60312.2024.10578747

Wang, J. (2024). Research and exploration on teaching c-language programming based on big data background. In 2024 *4th International Symposium on Computer Technology and Information Science*, ISCTIS 2024 (pp. 312–315). Institute of Electrical and Electronics Engineers Inc. doi:10.1109/ISCTIS63324.2024.10698846

Wang, J., & Wang, Y. (2024). Application of IoT and cloud computing technologies in smart campus: architecture challenges and solutions. In Proceedings of 2024 *2nd International Conference on Internet of Things and Cloud Computing Technology*, IoTCCT 2024 (pp. 146–152). Association for Computing Machinery, Inc. doi:10.1145/3702879.3702905

Wang, S. I.-C., Fang, C.-Y., & Liu, E. Z.-F. (2024). A literature review on the evaluation of e-learning effectiveness in taiwanese corporations. *Eurasian Journal of Educational Research*, 2024(112), 131–156. doi:10.14689/ejer.2024.112.08

Wang, X. (2025). Design and CIPP Evaluation of an ai-powered personalized learning platform for cross-border e-commerce. In *2025 IEEE International Conference on*

Electronics, Energy Systems and Power Engineering, EESPE 2025 (pp. 292–304). Institute of Electrical and Electronics Engineers Inc. doi:10.1109/EESPE63401.2025.10987066

Yamin, M. M., Imran, A. S., & Katt, B. (2023). Towards a digital twin for lifelong learning. In 2023 *4th International Conference on Computing, Mathematics and Engineering Technologies*: Sustainable Technologies for Socio-Economic Development, iCoMET 2023. Institute of Electrical and Electronics Engineers Inc. doi:10.1109/iCoMET57998.2023.10099333

Yan, S., Eng, L. G., & Seong, L. C. (2024). Influencing factors of continuous intention to use e-learning system of undergraduates in guangxi, china: the mediating role of perceived ease of use and perceived usefulness. *SAGE Open*, 14(4). doi:10.1177/21582440241305231

Zhang, P., Li, X., Pan, Y., Zhai, H., & Li, T. (2023). Global trends and future directions in online learning for medical students during and after the COVID-19 pandemic: A bibliometric and visualization analysis. *Medicine* (United States), 102(50), E35377. doi:10.1097/MD.0000000000035377

Zhang, Y. (2023). Construction of a smart classroom for image processing courses in colleges and universities based on artificial intelligence: taking fundamentals of photoshop as an example. In M. T.-.H. (Ed.), Proceedings of the *3rd IEEE International Conference on Social Sciences and Intelligence Management*, SSIM 2023 (pp. 84–88). Institute of Electrical and Electronics Engineers Inc. doi:10.1109/SSIM59263.2023.10469561