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Bibliometric analysis of e-material research in higher education based on WoS database

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Abstract

This study conducts a bibliometric analysis to map the intellectual landscape, evolutionary trends, and future directions of e-material research in higher education over the past three decades. Based on 348 research articles retrieved from the Web of Science (WoS) Social Sciences Citation Index (SSCI) database, this study employs descriptive statistical analysis, co-citation analysis, and keyword co-occurrence analysis to quantitatively and qualitatively assess the field's development. The analysis reveals four distinct growth stages: initial exploration (1995-2007), steady growth (2008-2013), rapid expansion (2014-2019), and explosive growth (2020-present), with the COVID-19 pandemic acting as a significant catalyst. The field is characterized by strong interdisciplinarity, with core knowledge bases in educational technology, psychology, and medical education. A "one superpower, multiple major powers" pattern is identified in national contributions, with the United States leading in output and the United Kingdom serving as the central collaboration hub. Keyword analysis indicates a shift from foundational topics like "higher education" and "technology" toward emerging frontiers such as "artificial intelligence," "self-regulated learning," and "digital divide." E-material research has matured into a dynamic and robust field. The core challenge has evolved from technological adoption to the meaningful integration and impact of e-materials on learning outcomes and equity. Future research should prioritize pedagogy-driven design, address the digital divide, and explore the long-term effects of AI integration. This review provides a systematic reference for researchers, policymakers, and practitioners to understand the past, present, and future of e-materials in higher education.

Keywords:

Literature review; E-material research; Educational technology; Self-regulated learning; Bibliometric analysis

1.Introduction

In an era of rapidly evolving academic research, the literature review has become an essential method for systematically synthesizing existing knowledge, identifying research gaps, and guiding future directions(Abunyewah et al., 2025; DiMatteo, 2004). With the rapid development of information technology, research in emerging fields such as digital learning, artificial intelligence in education, and blended learning has surged dramatically(Souza & Debs, 2024). For instance, data from the Web of Science Core Collection shows that the annual publication volume in the field of educational technology has grown from fewer than 100

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articles in the early 2010s to nearly 1,000 in 2024, an increase of more than tenfold. This explosive growth highlights the vitality of the field but also presents a significant challenge for researchers in integrating vast amounts of literature, distilling key findings, and advancing theoretical innovations(Serdyukov, 2017).

In recent years, educational technology research has shown multidimensional development(Olateju Temitope Akintayo et al., 2024; Pogoda et al., 2019). Early scholars, such as Helle et al. (2013), focused on the impact of multimedia learning on cognitive abilities, while recent studies by researchers have started to explore the educational potential of generative artificial intelligence. Database analyses reveal that the keyword "Generative AI" has emerged with a burst strength of 2.88 between 2023 and 2025, marking it as the latest frontier(AlShaikh et al., 2024; Moreno & Mayer, 1999; Roy, 2024). However, due to the fragmented nature of research topics, methodological differences, and the diversity of interdisciplinary perspectives, existing literature has yet to form a unified theoretical framework(Eberle et al., 2019; Fourqoniah et al., 2025). For example, empirical research on the digital divide shows a significant imbalance between developed and developing countries, and longitudinal data to assess the long-term impact of learning outcomes is still lacking.

In this context, this study employs a systematic literature review approach to integrate key research in educational technology from authoritative databases such as Web of Science.

2.Research design

To ensure the quality and authority of the literature, this study used the Web of Science (WoS) Core Collection as the sole data source, focusing specifically on journals indexed in the Social Sciences Citation Index (SSCI) to capture high-impact research in the fields of social sciences and education.

The data retrieval was conducted on August 16, 2024. A systematic search strategy was employed using keywords such as "e-material," "digital material," and their related variants to comprehensively cover the research topic. The search was primarily applied to the title, abstract, and keywords fields of the publications to ensure precise retrieval of relevant research.

The initial search resulted in a pool of publications. Through a rigorous screening process that included removing duplicates and excluding studies unrelated to the core theme of digital teaching/learning materials (such as those focused solely on materials science in non-educational contexts), a final set of 348 relevant research articles was identified. This refined dataset serves as the foundation for all subsequent bibliometric analysis.

This study employs bibliometric analysis to conduct both quantitative and qualitative analysis of the 348 articles. The analysis will be conducted from several perspectives:

Descriptive Statistical Analysis: To outline the basic characteristics of the field, including the annual publication trend, leading contributing countries/regions, core institutions, and influential authors.

Co-citation Analysis: To map the intellectual structure of the field by identifying clusters of frequently co-cited references and foundational knowledge bases.

Keyword Co-occurrence and Cluster Analysis: To identify core research topics, emerging trends, and the

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conceptual evolution within the field. Keywords with significant citation bursts will be analyzed to detect frontier topics.

The analysis will be supported by specialized bibliometric software such as CiteSpace or VOSviewer to generate visual network maps and perform computational analysis, ensuring the objectivity and depth of the findings.

3.Data analysis

3.1Descriptive analysis

Based on the provided publication data on digital textbooks in the WOS SSCI database, the following is an analysis and summary of the trends:

Initial Stage (1995–2007): During the period from 1995 to 2007, research output was minimal, with annual publications ranging from 1 to 4 articles. The earliest publications appeared in 1995 and 1997 (1 article each), followed by 2 articles in 2002. A gradual increase began in 2003, reaching 4 articles by 2007. This period represents the embryonic stage of digital textbook research, with limited scholarly attention, as the application of the internet and digital technologies in education was still in its infancy.

Steady Growth Stage (2008–2013): From 2008 to 2013, research output began to grow steadily, with notable increases in 2011 and 2012, reaching 8 and 6 articles, respectively. Although the overall publication volume remained relatively low, this stage marked growing interest in the field. The rise of Web 2.0 technologies and the increasing adoption of smart devices contributed to the recognition of digital textbooks as a component of educational technology. The demand for digital tools in education also grew following the 2008 financial crisis.

Rapid Growth Stage (2014–2019): Starting in 2014, research output saw a significant increase, entering a phase of rapid growth. Publications reached 14 articles in 2014, followed by 10 in 2015, 12 in 2016, 14 in 2017, and 17 in 2018. In 2019, the number surpassed 20, reaching 21 articles. This period reflects an accelerated growth phase for digital textbook research, driven by advancements in educational technologies such as MOOCs, blended learning, and adaptive learning. Scholars began to explore the diversity, application models, and educational impacts of digital textbooks in greater depth.

Explosive Growth Stage (2020–2024): From 2020 onward, research on digital textbooks experienced explosive growth, particularly following the outbreak of the COVID-19 pandemic, which spurred global demand for online education. Publications increased from 27 articles in 2020 to 31 in 2021, 33 in 2022, 39 in 2023, and 47 in 2024. During this period, digital textbooks transitioned from an optional research topic to a critical area of study. Research expanded to include emerging topics such as artificial intelligence, personalized learning, and open educational resources.

Although data for 2025 is incomplete, current trends suggest that publication output will remain high, with an estimated 38 articles. This indicates sustained research interest in digital textbooks, driven by ongoing technological advancements and increasing demand for digital education solutions. The field is expected to

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remain highly active in the near future.

Research in this field started slowly, with steady accumulation over the years before entering a phase of rapid growth. The post-2020 period, driven by the pandemic, saw an explosive increase in publication volume. The year 2020 marked a significant turning point, as the global shift in education systems made digital textbooks a central focus of educational research. The high projected publication volume for 2025 suggests that research on digital textbooks will remain vibrant, particularly with the integration of emerging technologies such as AI and AR/VR, which will further deepen and expand the scope of research.The data highlights the immense potential of digital textbooks as a research field, evolving from a niche academic topic into a core direction in global education research.

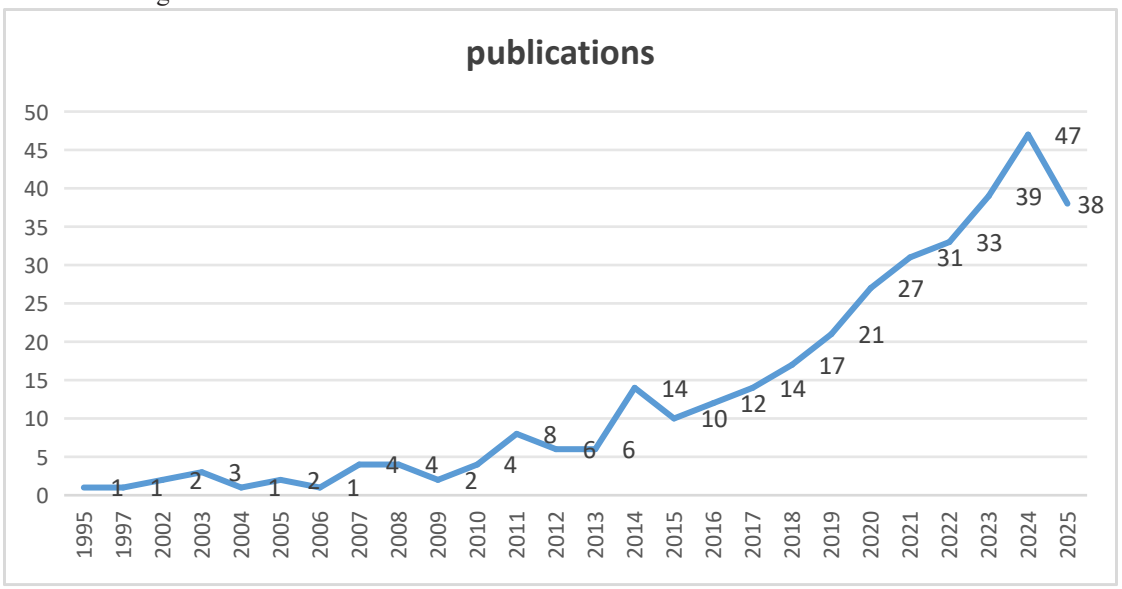


Figure 1 publications

3.2statistics of co-cited journals

This dataset, likely generated through bibliometric methods (e.g., using CiteSpace), reveals the most influential and active core academic journals in the field of "digital textbooks" or "educational technology." The analysis can be summarized from the following perspectives:

The data indicates the formation of a distinct core journal cluster, which serves as a critical foundation for knowledge in this field. Computers & Education and Computers in Human Behavior lead with significant dominance (high Frequency and Centrality), establishing them as the most foundational and widely recognized sources of knowledge, with their research outputs extensively cited. Following closely are journals such as British Journal of Educational Technology, Journal of Educational Psychology, and Journal of Computer Assisted Learning, which together form a stable cluster of high-quality literature sources that underpin the discipline's development.

The disciplinary origins of these journals highlight the interdisciplinary nature of the field. Its knowledge base draws not only from explicit educational technology journals (e.g., Computers & Education, BJET) but also heavily relies on:

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Psychological Perspectives: Journals like Computers in Human Behavior, Journal of Educational Psychology, Educational Psychology Review, and Contemporary Educational Psychology focus on human learning behaviors, cognition, and psychological mechanisms in technology-enhanced environments.

Medical Education Perspectives: Journals such as Academic Medicine, BMC Medical Education, and Medical Education indicate that the application of digital textbooks in professional education, particularly in medicine, is a significant subfield.

Distance and Open Education Perspectives: Journals like Internet and Higher Education, Distance Education, and The International Review of Research in Open and Distributed Learning underscore the critical value of digital textbooks in overcoming spatial and temporal barriers.

This interdisciplinary nature suggests that digital textbook research extends beyond mere technological applications, encompassing deeper issues in pedagogy, learning sciences, and psychology.

The "Burst" indicator is crucial, as it identifies journals with a rapid surge in influence during specific periods, revealing the evolution of research frontiers.Early Hotspots (2012–2018): The burst of British Journal of Educational Technology (2012–2018) and Internet and Higher Education (2012–2017) reflects the early wave of exploration into the integration of digital textbooks with online learning and higher education.

Mid-Term Deepening (2017–2021): The burst of Review of Educational Research (2017–2021) is significant, indicating a shift from specific applications to systematic reviews and meta-analyses, marking the field's maturation and reflective phase.

Current Frontiers (2021–Present): Recent high-burst journals clearly point to the latest research directions:-Journal of Educational Psychology (2018–2023): Continued focus on deepening understanding of cognitive and psychological mechanisms underlying learning.Education and Information Technologies (2021–2025) and Sustainability: Reflect strong attention to artificial intelligence in education and sustainability education. Educational Psychology Review (2022–2023) and Contemporary Educational Psychology: Reaffirm the prominence of understanding human-computer interaction in learning from a psychological perspective.BMC Medical Education (2022–2023): Indicates that the digital transformation of medical education remains a sustained hotspot.

In summary, the knowledge base of this field is built upon a core journal cluster from educational technology, learning sciences, and psychology, demonstrating strong interdisciplinary characteristics. Research hotspots have evolved from early explorations of technology applications and online education to a deeper focus on the psychological mechanisms of learning, the integration of artificial intelligence, and applications in specialized domains such as medicine. Journals with high burst strength provide researchers with clear indicators of the latest and most active research frontiers and literature sources.

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Table 1 Top 25 co-cited journals and burstness of co-cited journals

Rank	Frequency	Degree	Centrality	Sigma	Co-cited journal	Year	Burst	Burst Begin	Burst End	Degree	Centrality	Sigma	Page Rank	Co-cited journal with burstness
1	152	99	0.2	1.76	Computers in Human Behavior	1997	3.05	2014	2016	99	0.2	1.76	0	Computer Education
2	79	95	0.14	1.47	British Journal of Educational Technology	2011	3	2015	2016	95	0.14	1.47	0	Computers in Human Behavior
3	90	89	0.12	1	American Educational Research Journal	2007	3.26	2012	2018	58	0.03	1.1	0	Learning and Instruction
4	20	83	0.13	1	Journal of Educational Psychology	2005	3.7	2016	2018	58	0.06	1.23	0	Review of Educational Research
5	43	73	0.05	1	Journal of Computer - Assisted Learning	2005	4.36	2018	2023	57	0.05	1.26	0	The Internet and Higher Education
6	55	72	0.09	1	Australasian Journal of Educational Technology	2008	2.78	2021	2023	44	0.08	1.25	0	Educational Technology & Society
7	36	63	0.05	1	Educational Psychology Review	2010	3.48	2019	2020	40	0.03	1.11	0	International Review of Research in Open and Distributed Learning
8	35	62	0.05	1	Academic Medicine	2012	3.77	2022	2023	32	0.02	1.09	0	International Journal of Educational Technology in Higher Education
9	22	59	0.1	1	BMC Medical Education	2003	4.16	2019	2022	31	0.07	1.33	0	Learning, Media and Technology
10	40	58	0.09	1	Learning and Instruction	2011	2.87	2022	2023	30	0.01	1.04	0	Contemporary Educational Psychology
11	39	58	0.03	1.1	Review of Educational Research	2012	4.09	2017	2020	24	0.01	1.06	0	Medical Education
12	35	58	0.06	1.23	The Internet and Higher Education	2014	2.88	2017	2021	23	0.01	1.04	0	Journal of Science Education and Technology
13	39	57	0.05	1.26	Applied Cognitive Psychology	2008	3.53	2012	2017	21	0.02	1.07	0	Journal of Learning Sciences
14	14	52	0.04	1	Educational Technology Research and Development	2004	4.3	2022	2025	19	0.01	1.04	0	Educational Science

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15	56	48	0.04	1	Educational Technology & Society	2004	5.4	2023	2025	18	0	1.03	0	Teaching and Teacher Education
16	38	44	0.08	1.25	Education and Information Technologies	2009	3.61	2019	2021	18	0.01	1.02	0	Proceedings of the Society for Behavioral Research
17	54	43	0.03	1	Educational Psychologist	2019	4.11	2021	2025	17	0.01	1.02	0	Sustainability
18	28	41	0.02	1	Instructional Science	2005	4.54	2023	2025	15	0	1.01	0	Frontiers in Education
19	22	40	0.05	1	Distance Education	2004	3.93	2021	2022	15	0.01	1.02	0	Journal of Medical Internet Research
20	31	40	0.07	1	International Review of Research in Open and Distributed Learning	2010	4.98	2013	2019	15	0.01	1.08	0	Journal of Adolescent and Adult Literacy
21	26	40	0.03	1.11	Higher Education Research and Development	2017	4.37	2017	2020	14	0	1.01	0	Open Learning: The Journal of Open and Flexible Learning
22	24	39	0.03	1	Academic Library and Higher Technology Gazette	2014	4.04	2023	2025	14	0	1	0	Journal of Computer in Higher Education
23	1	38	0	1	Aslib Proceedings	2002	4.11	2023	2025	13	0.01	1.03	0	PLOS ONE
24	1	38	0	1	American Journal of Physics	2002	6.32	2017	2020	13	0.01	1.05	0	Thesis
25	2	38	0.06	1	Computers in Human Behavior	1997	3.18	2018	2020	11	0	1	0	International Journal of Educational Research

3.3 Scholarly contribution

Data analysis reveals a distinct "one superpower, multiple major powers" pattern in global digital education research: The United States dominates with 82 publications (Freq) and peak research activity during 2017-2018 (Burst=7.29); while the UK (England) ranks second with 40 publications but serves as the central hub of international collaboration networks with the highest centrality (0.52). Research capabilities are concentrated in developed countries, with Taiwan region of China (30 publications, Burst=3.47), Spain (26), Australia (25) and mainland China (22) forming a strong secondary tier. Although the list covers 25 countries/regions worldwide, research distribution shows significant imbalance—developed Western countries maintain dominance while developing regions demonstrate limited participation. This landscape closely correlates with national economic-technological capabilities, educational investment levels, and the prevailing English academic ecosystem.

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Based on the provided data on authors in the field of digital education, the research shows clear signs of phase transitions and regional distribution characteristics. Early researchers, such as Helle and Gourlay, emerged in 2012, marking the exploratory stage of this field. During the period from 2019 to 2020, researchers like Sage and Lambert drove the development of the field. In the past three years (2022-2025), a new wave of emerging researchers, including Chen and Buggenhagen, has appeared, with Buggenhagen being the most influential scholar in recent years, with a burst strength of 2.88.

In terms of research duration, the impact cycle of early researchers was relatively short (1-3 years), while the influence of more recent researchers is expected to last longer (3-4 years), indicating that the research in this field is deepening and becoming more sustained. It is noteworthy that the researchers' surnames reflect diverse cultural backgrounds, highlighting the international nature of the field. However, it also indicates that the research power is still primarily dominated by scholars from Europe and North America.

This data reveals that the field of digital education is in a rapid development phase, with the new generation of researchers driving the field towards deeper exploration. It is expected that more significant research outcomes will emerge in the coming years.

Based on the statistical results of research institutions in the field of digital teaching and learning, the following summary can be drawn:

The data reveals the influence and activity of core institutions in the global digital teaching and learning research landscape. Overall, U.S. institutions hold a quantitative advantage, while German institutions demonstrate strong recent momentum. Research strength exhibits a pattern of being "decentralized yet collaborative," with distinct generational differences in the active research periods of various institutions.

The result includes numerous American universities and university systems, such as the University of California System, Harvard University, and the Indiana University System, highlighting the deep research foundation and large scale of the U.S. in this field.German institutions are particularly prominent. Johannes Gutenberg University of Mainz (Burst Strength 2.91, 2023-2025) is currently the most active institution. Simultaneously, institutions in Berlin (e.g., Humboldt University, Free University of Berlin, Charité – Universitätsmedizin) form a significant cluster, indicating that Germany, especially Berlin, has become an emerging hub for digital teaching and learning research.

Institutions like the University of California System (2015-2018), Kent State University (2015-2017), and National Taiwan University (2014-2017) were early entrants into the field and exerted influence.A cohort of institutions has become active within the past five years, including several in Germany, Harvard University (2022-2025), and the Indiana University System (2021-2023). This reflects the sustained research interest and the geographical diffusion of activity.The frequent appearance of research entities categorized as "university systems" (e.g., University of California System, University System of Ohio, State University System of Florida) suggests that resource sharing and collaboration across campuses is a significant model for enhancing overall research capacity in digital teaching and learning.Beyond traditional comprehensive universities, the list includes policy research bodies like the European Commission Joint Research Centre and specialized institutions such as Charité – Universitätsmedizin, reflecting the broad integration of digital teaching and learning research with various application contexts.

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In conclusion, the global landscape of research institutions in digital teaching and learning is dynamically evolving: the United States maintains leadership through the scale of its higher education system, while Germany is rapidly rising as a new influential force. Research activity advances in waves across different institutions and regions, with recent hotspots clearly shifting towards Europe, particularly Germany. Furthermore, the synergistic effect of university systems and participation from diverse institution types collectively drives the breadth and depth of research in this field.

3.4Keyword Analysis

The co-occurrence analysis of keywords in the field of digital teaching research provides a comprehensive overview of its core issues, knowledge structure, and evolving trends. This analysis highlights the shifting focus from technology integration to broader educational concerns, and it reflects the ongoing transformation of educational practices in response to technological advancements.

Core Research Landscape: Focusing on Higher Education and Technology Integration. The data reveal a well-established and multi-layered research structure within this field, with the primary focus on the integration of technology in higher education and its impact on student learning. Keywords such as higher education (frequency 64, burst strength 5.69), students (frequency 35), technology (frequency 29, burst strength 3.51), and education (frequency 32) dominate the research landscape in terms of frequency and centrality. Of particular note, the keyword higher education shows consistent bursts through 2025, indicating that the digital transformation of higher education continues to be the most active and dynamic area of research.

Key Research Themes: From Macro-Level Concepts to Micro-Level Practices. The research themes within digital teaching can be categorized into several interconnected dimensions:

1. Pedagogical Approaches and Instructional Design: Research focuses on how to effectively incorporate technology into teaching and learning environments. Key terms such as design, instructional strategies, blended learning, and flipped classroom emphasize the development of pedagogical frameworks and strategies that leverage technology to enhance the teaching process.

2. Learning Psychology and Outcomes: This theme examines how technology influences learners' intrinsic motivations and external academic performance. Keywords like motivation, performance, engagement, self-regulated learning, and academic performance reveal a strong interest in understanding the psychological and behavioral aspects of learning in digital environments.

3. Digital Competencies and Literacy: Keywords such as media literacies (with significant burst strength), digital literacy, and information literacy highlight the increasing focus on building digital competencies among both educators and students. This trend indicates a recognition of the importance of fostering skills that enable effective navigation and critical engagement with digital tools and content.

4. Acceptance and Influencing Factors: Research on acceptance, perceptions, and attitudes reflects an ongoing exploration of the psychological, social, and cultural factors that influence the adoption and use of digital teaching practices. These factors are crucial for understanding the barriers and enablers of technology integration in education.

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Research Methods and Theoretical Foundations: Bridging Empirical Studies and Educational Theory. The emergence of terms such as case study, meta-analysis, self-efficacy, and cognitive load theory suggests a well-developed methodological approach within the field. The research blends empirical evidence with educational and psychological theories, enhancing the depth and rigor of studies and providing a robust theoretical framework for understanding digital teaching dynamics.

Recent keyword bursts indicate a shift toward new technologies and methodologies that promise to shape the future of digital teaching:

1. Artificial Intelligence Integration: Keywords like artificial intelligence have emerged as significant topics, indicating that intelligent systems, such as AI-powered personalized learning, will become central to the field of digital teaching in the near future.

2. Immersive Learning Experiences: The appearance of terms such as virtual reality, augmented reality, and gamification suggests that research is moving toward more interactive and immersive learning environments. These technologies promise to create engaging, hands-on experiences that enhance the learning process.

3. Equity and Accessibility: The increasing focus on terms like digital divide and open educational resources highlights the growing concern with educational equity. This research is concerned with ensuring that digital teaching practices and resources are accessible to all learners, regardless of socio-economic background, and that digital tools do not exacerbate existing educational inequalities.

Digital teaching research has evolved from a narrow focus on technology application to a mature, multidimensional, and interdisciplinary field. While the core focus remains on higher education, the research is rapidly evolving towards intelligent, immersive, and personalized learning environments. Furthermore, it continues to address fundamental issues related to instructional effectiveness, learner experience, and educational equity. As the field advances, it will likely play a pivotal role in shaping the future of education in the digital age.

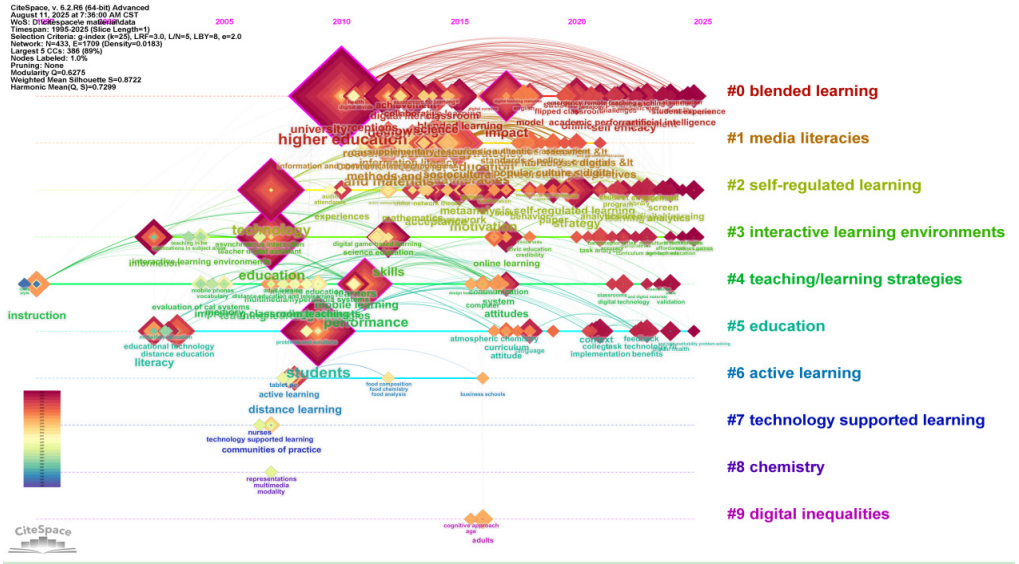


Figure 2 timeline of keywords

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4.Discussion and conclusion

4.1 Discussion

This bibliometric analysis provides a comprehensive mapping of the intellectual landscape of e-material research in higher education over the past three decades. The findings illuminate not only the quantitative growth and structural composition of the field but also offer profound insights into the dynamics driving its evolution.

First, the four distinct stages of publication growth—from initial exploration to explosive expansion—closely mirror the trajectory of technological adoption in society and education at large(Shalihati et al., 2025). The embryonic and steady growth stages (1995-2013) align with the proliferation of the internet and Web 2.0 technologies, where digital materials were a novel adjunct to traditional pedagogy(Maynard & O'Brien, 2010). The rapid growth stage (2014-2019) corresponds with the maturation of MOOCs, blended learning models, and adaptive learning technologies, prompting deeper inquiries into the pedagogical integration of e-materials(Danysko & Semenovska, 2018). Most significantly, the explosive growth stage (2020-present) underscores the profound impact of the COVID-19 pandemic as a critical juncture or "external shock" that forcibly accelerated the digital transformation of global higher education(Johnson, 2020). This period transformed e-materials from an option to a necessity, validating earlier research and spawning new lines of inquiry into their efficacy, accessibility, and design under conditions of emergency remote teaching(Donohue et al., 2021).

Second, the interdisciplinary nature of the field, as evidenced by the co-cited journal analysis, is a key strength(Abdi et al., 2024). The strong presence of journals from educational psychology, medical education, and distance learning indicates that e-material research is not a siloed technical field but a complex domain situated at the intersection of learning science, instructional design, and domain-specific practices. This suggests that effective e-material design requires a synergistic understanding of how technology, cognition, and context interact(Videla-Reyes et al., 2023). The recent burst of journals like Computers in Human Behavior and Journal of Educational Psychology further emphasizes a shift towards understanding the human factors—motivation, self-regulation, cognitive load—in digital learning environments, moving beyond a purely technocentric view(Wiederhold, 2020).

Third, the "one superpower, multiple major powers" pattern in national contributions reflects broader global inequalities in research capacity, funding, and technological infrastructure(Jokhadze et al., 2024). The dominance of the U.S. and other developed economies, coupled with the central brokerage role of the UK, highlights how the research agenda is shaped by a few core countries(Fusco et al., 2020; Kholin, 2025). This raises important questions about geographic and linguistic bias in the literature, as findings from Western, educated, industrialized, rich, and democratic contexts may not fully translate to other educational settings. The emerging strength of Germany, particularly in recent years, points to the role of targeted national policy and investment in fostering research hubs. Future efforts should encourage greater participation from developing regions to ensure the development of inclusive and globally relevant e-material solutions.

Finally, the keyword evolution reveals the field's response to technological trends. The enduring focus on

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"higher education," "students," and "technology" confirms the stable core of the field. However, the emergence of keywords like "artificial intelligence," "virtual reality," "self-regulated learning," and "digital divide" signals a maturation of research questions. The focus is expanding from simply implementing technology to exploring how it can enable personalized, immersive, and equitable learning experiences. This aligns with calls for a more critical approach to EdTech that prioritizes pedagogical goals over technological novelty and addresses persistent challenges of equity and access.

4.2 Conclusions

This study leads to several overarching conclusions about the state of e-material research in higher education:

The field has achieved maturity and sustained momentum. From a niche interest, it has grown into a robust, interdisciplinary field with a rapidly expanding knowledge base. The pandemic served as a definitive catalyst, cementing the central role of e-materials in contemporary higher education. The high projected output for 2025 indicates that this momentum is not fleeting but represents a new normal.

The research landscape is concentrated yet dynamic. Research production and influence are concentrated in a core set of journals, leading developed nations, and elite institutions. However, within this structure, there is dynamic activity, with new hubs emerging (e.g., Germany) and research frontiers continuously evolving towards more complex issues of learning personalization, immersion, and equity.

The core challenge has shifted from adoption to integration and impact. The fundamental question is no longer if e-materials should be used, but how they can be effectively integrated to enhance learning outcomes, support diverse learners, and foster essential digital literacies. The field is increasingly characterized by a critical, evidence-based approach that seeks to understand the conditions under which e-materials succeed or fail.

In summary, this bibliometric review paints a picture of a field that is both technologically astute and increasingly pedagogically sophisticated. The evolution of e-material research reflects the broader journey of higher education's digital transformation, highlighting its potentials, its disparities, and its unwavering focus on improving student learning.

5.Future agenda and limitation

Based on the findings, future research should:

Deepen Investigate AI Integration: Explore the pedagogical ethics, effectiveness, and long-term impact of AI-driven personalization and generative AI in e-material creation and use.

Address the Digital Divide: Conduct more studies in under-represented geographical contexts to develop strategies that mitigate digital inequities in access to and use of e-materials.

Promote Pedagogical-Driven Design: Shift focus from technology features to learning-centered design, exploring how e-materials can best support specific pedagogical approaches like collaborative problem-solving and critical thinking.

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Longitudinal and Ecological Studies: Move beyond short-term case studies to conduct longitudinal research that examines the sustained impact of e-materials on student success and faculty teaching practices in authentic settings.

This study has several limitations. First, it relied solely on the WoS SSCI database, which, while authoritative, may exclude high-quality research published in journals not indexed therein (e.g., some regional or open-access journals). Second, the bibliometric approach primarily reveals structural patterns and trends; it cannot capture the nuanced findings and methodological details of individual studies. Qualitative systematic reviews are needed to supplement these findings. Finally, the data for 2025 is incomplete, so the trends for the most recent period should be interpreted with caution.

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