Global Trend Digital Teaching Material For Improving Critical Thinking Skill: A Bibliometric Analysis (2016-2026)

Elisabeth Irma Novianti Davidi[1], Yuliana Wahyu[2], Kanisius Supardi[3]
{irmadavidiparta@gmail.com[1], yulianawahyu76@gmail@gmail.com[2] kanisiussupardi55@gmail.com [3]}

St. Paul Catholic University, Indonesia[123]

Abstract. This study offers a comprehensive bibliometric analysis of global patterns in digital educational resources designed to foster critical thinking abilities over the period 2016–2026. Utilizing data from Scopus and Dimensions databases, the research analyzes publication trends, citation impacts, and thematic evolutions using VOSviewer and Biblioshiny. The results reveal an exponential surge in publication volume, particularly post-2020, with Dimensions recording significantly higher data density than Scopus. Geographically, Indonesia dominates productivity in Scopus, while the US and UK lead in collaborative network strength and citation impact. However, co-authorship analysis indicates significant fragmentation, particularly in Scopus-indexed research. The findings suggest that while the field is maturing, there is a critical need for cross-border collaboration and the integration of niche themes like "flipped learning" and "augmented reality" into mainstream pedagogy. This study provides a strategic roadmap for educators and policymakers to design technology-mediated materials that foster higher-order thinking in an AI-driven information ecosystem.

Keywords: bibliometric analysis; critical thinking; digital teaching materials; artificial intelligence; digital pedagogy.

1 Introduction

The ascendancy of critical thinking as a paramount educational objective is not merely an academic trend but a consolidated global policy priority. National educational frameworks worldwide are increasingly mandating the integration of such higher-order skills into curricula, recognizing them as essential for innovation and workforce adaptability [1]. This policy-driven imperative provides a significant catalyst for the research and development of innovative pedagogical tools, including digital teaching materials. Concurrently, the evolution of digital tools themselves—from basic repositories to interactive platforms incorporating artificial intelligence and adaptive learning pathways—has created unprecedented opportunities to translate policy into practice [2]. The confluence of these factors has generated a dynamic and expanding corpus of academic literature seeking to evaluate, validate, and refine digital interventions aimed at fostering critical thought. This burgeoning field, however, is

ICEHHA 2025, December 11-12, Ruteng, Indonesia

DOI 10.4108/eai.11-12-2025.2363104

characterized by diverse methodologies, contextual applications, and theoretical underpinnings, necessitating a systematic effort to map its intellectual contours and trajectories.

Despite the proliferation of digital tools and a rich body of pedagogical research on critical thinking, a significant analytical gap persists. Existing scholarship often remains siloed within specific disciplines, educational levels, or regional contexts. For instance, while studies explore digital storytelling in language arts or simulations in STEM, comprehensive analyses that transcend these boundaries are scarce [3] . Similarly, research output and influence show notable disparities between world regions . While systematic and qualitative reviews abound, there is a distinct lack of comprehensive, longitudinal mapping of the global intellectual structure, evolution, and collaborative networks driving research at the intersection of digital teaching materials and critical thinking skill development [4]. A bibliometric analysis, which quantitatively examines publication patterns, citations, keywords, and author affiliations, is uniquely positioned to illuminate these macro-trends [5]. Such an analysis can move beyond individual case studies to identify dominant research fronts, emerging themes, influential scholarly communities, and geographical centers of innovation, thereby revealing the field's underlying architecture and trajectory.

The domain of "digital teaching materials" itself has evolved dramatically within the 2016-2026 scope, expanding from static digital reproductions of textbooks to dynamic, interactive, and intelligent resources. Modern materials are increasingly designed around pedagogies proven to cultivate critical thinking, such as inquiry-based learning, where digital environments scaffold students through cycles of questioning, investigation, and reflection [6] . These resources leverage learning management systems (LMS) to host interactive modules that prompt analysis, employ simulations for problem-based learning, and integrate functionalities like adaptive feedback. The primary educational challenge revolves around how the design of these materials can effectively support the cultivation of specific critical thinking skills—such as analysis, evaluation, and inference—while simultaneously fostering foundational dispositions like open-mindedness. [7]. Current research trends highlight their application in hybrid and distance learning environments, where strategic digital use is crucial for fostering deep cognitive engagement outside traditional classrooms [8].

Preliminary bibliometric investigations in adjacent educational fields underscore the value of this approach. For example, a bibliometric analysis of research on critical thinking within English Language Teaching (ELT) revealed China as the most prolific contributing country and underscored a transition of thematic focus from collaborative learning toward the integration of language and thinking skill instruction over time [9]. Another study on quality assurance in higher education used bibliometric methods to delineate clear phases of research evolution and identify "motor themes" like technological pedagogy and sustainability. These examples demonstrate how bibliometrics can effectively chart the maturation of a scholarly domain. They provide a precedent for applying similar analytical rigor to the specific nexus of digital teaching materials and critical thinking, promising insights into the field's foundational works, current frontiers, and network of contributing scholars and institutions [10].

To bridge this research gap, the present study utilizes a bibliometric approach to map global research trends concerning digital instructional materials for critical thinking over the decade from 2016 to 2026. By analyzing a corpus of literature from major indices like Scopus and Web of Science, this research question are:

1. **RQ1:** What are the anual trends in Digital Teaching Material For Improving Critical Thinking Skill based on publication and citation per year 2015-2025?
2. **RQ2:** What characterizes the collaborative patterns among the most highly cited and influential authors currently working on digital teaching materials for enhancing critical thinking skills?
3. **RQ3:** What are the research gaps and novelty in Digital Teaching Material For Improving Critical Thinking Skill for upcoming research?

The findings will provide a synthesized, evidence-based overview of the field's development, offering scholars a clear roadmap of past achievements and future directions. For educators and policymakers, this analysis will highlight evidence-supported practices and tools, informing the design of professional development and the strategic integration of technology to cultivate the critical thinkers needed for a complex future.

2 Method

2.1 Research Design

This study seeks to investigate contemporary trends in science education that integrate local wisdom at the elementary school level. The research adopts a mixed-methods approach, drawing on diverse data sources and framed within a descriptive survey model. To accomplish this objective, the study utilizes two analytical techniques: bibliometric and descriptive analysis. These methods are applied to examine existing academic literature on science learning integrated with local wisdom at the elementary students level. Bibliometric analysis, which evaluates a subject's development, scholarly quality, influence, and relevant resources, has grown in popularity across various disciplines [11] [12]. While not a replacement for conventional literature reviews, it serves as a crucial complementary tool [13].

Meanwhile, the descriptive analytical approach involves gathering and interpreting data within established thematic categories. In general, bibliometric analysis serves two main purposes: performance analysis and the mapping of scientific knowledge. [14]. Performance analysis assesses the volume and influence of scholarly output from various contributors, including institutions, authors, and countries. In contrast, scientific mapping employs visualization techniques to elucidate the intellectual structure and evolving dynamics within a particular research domain.

2.2 Data Collection

The data for this investigation were drawn from the Scopus and Dimensions databases, chosen for their extensive coverage of peer-reviewed scholarly literature. The search was conducted on Nov 24, 2025, using the Boolean search string: "digital teaching" AND "critical thinking" AND ("elementary students" OR "primary students"). At the same time, the systematic review and meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which encompass four key stages: identification, screening, eligibility assessment, and final inclusion. [15].

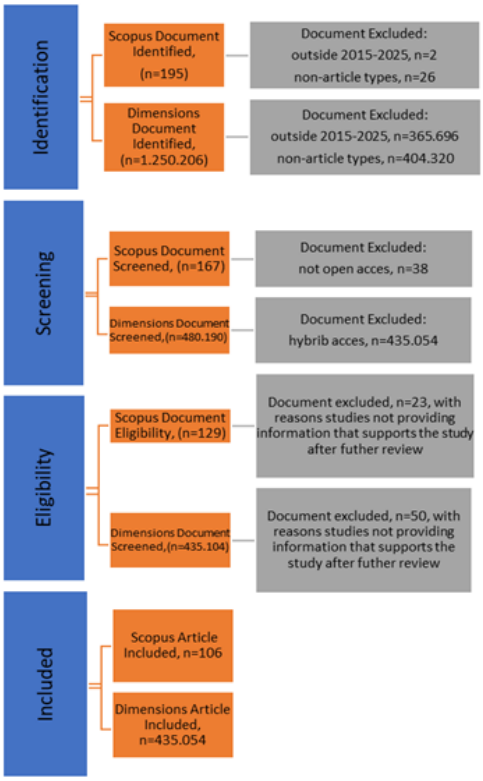

Figure 1. Prisma Flow Chart

Reffering to Figure 1. during the identification stage 2 documents were excluded for outside 2015-2025 and 26 documents were excluded non-article types (for Scopus databases); 365.696 documents were excluded for outside 2015-2025 and 404.320 documents were excluded non-article types (for Dimensions databases). During Screening stage, 38 documents were excluded for not open acces (for Scopus databases) and 435.054 documents were excluded hybrid acces (for Dimensions databases). In the eligibility phase, 23 documents (Scopus databases) and 50 documents (Dimensions databases) were excluded with reason studies not providing information for supports the study after future review. Ultimately, 106 Sopus documents and 435.054 Dimensions documents were included in the bibliometrics análisis-depth qualitative análisis and deep descriptive analysis.

2.3 Data Analysis

This study adopted a dual analytical approach, integrating both bibliometric and descriptive methods. The descriptive component was used to examine articles based on several criteria, including publication year, country of origin, and authorship patterns. Meanwhile, the bibliometric analysis employed various techniques such as citation analysis (at the author and

country levels), co-authorship analysis (involving both authors and their affiliated countries), author keyword co-occurrence analysis, and term co-occurrence analysis. To conduct these analyses and generate visualizations, the study utilized VOSviewer version 1.6.16—a software tool developed by Van Eck and Waltman—alongside R Studio [16] Written by JAVA and accessible at www.vosviewer.com, along with the Biblioshiny application, this free software enables the visualization and exploration of maps derived from network data. The network maps produced using VOSviewer and Biblioshiny in this study are accompanied by accessible links to facilitate a more detailed examination of the connection strength associated with each node.

3 Results

The findings of this study cover multiple dimensions of science education that integrate local wisdom for elementary students. The analysis addresses the central research questions by exploring key areas such as publication trends, citation patterns, the most influential authors, country-level contributions, co-authorship networks among researchers, and international collaboration patterns. Each of these aspects is examined in detail to provide a comprehensive understanding of the research landscape.

RQ1: What are the annual trends in Digital Teaching Material For Improving Critical Thinking Skill based on publication and citation per year 2015-2025?

3.1 Annual Trend of Publications and Citations

3.1.1 Publication Trend

The bibliometric examination of publication trends between 2015 and 2025 reveals a pronounced divergence in research indexing patterns between the Scopus and Dimensions databases concerning digital instructional materials for critical thinking. Scopus coverage appears minimal, showing a negligible increase from a single document in 2015 to only 32 documents in 2025, suggesting that this specific niche is either underrepresented in Scopus-indexed high-impact journals or is still in a nascent stage within that specific dataset. In contrast, the Dimensions database captures a massive proliferation of scholarship, surging exponentially from 512 documents in 2016 to 11,487 in 2026, indicating that the broader academic community is actively and aggressively prioritizing this field of inquiry.

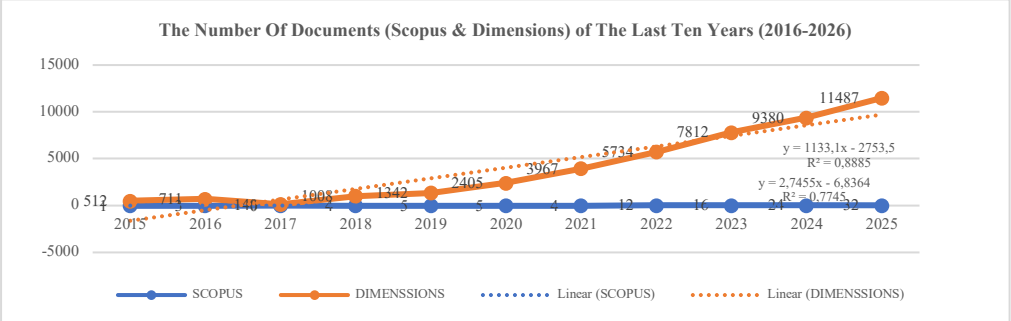

Figure 2. Global Trend Digital Teaching Material For Improving Critical Thinking Skill: A Bibliometric Analysis (2016-2026)

3.1.2 Citation Trend

The bibliometric analysis of research concerning Global Trend Digital Teaching Material For Improving Critical Thinking Skill: A Bibliometrıc Analysıs (2016-2026)' reveals a field characterized by a disparity between publication volume and citation impact over time. The citation analysis on Table 1. shows that indicates a distinct non-linear relationship between publication volume and scholarly impact over the observed decade.

Table 1. Average Citations Per Year (Scopus Databases)

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2015	7,00	1	0,64	11
2016	4,67	3	0,47	10
2018	6,25	4	0,78	8
2019	30,20	5	4,31	7
2020	8,00	5	1,33	6
2021	7,50	4	1,50	5
2022	8,50	12	2,12	4
2023	14,62	16	4,87	3
2024	3,46	24	1,73	2
2025	0,91	32	0,91	1

While the number of citable documents (N) shows a consistent upward trajectory, peaking at 32 publications in 2025, the highest impact per article was recorded significantly earlier. Specifically, 2019 emerges as a seminal year for this field; despite a modest output of only 5 documents, it achieved the highest Mean Total Citations per Article (30.20) and a high annual citation rate (4.31). This suggests that foundational research published during this period has driven the theoretical underpinnings of the field, continuing to garner significant academic attention despite the lower volume of papers produced at that time.

In contrast, the data for the most recent years reflects a surge in productivity accompanied by the natural latency of citation accumulation. The year 2023 represents a notable outlier in the recent trend, balancing a rising publication count (N=16) with a substantial impact factor of 14.62 citations per article and the highest recorded Mean Total Citations per Year (4.87). However, the sharp decline in mean citations for 2024 (3.46) and 2025 (0.91), despite 2025 having the highest publication volume (N=32), illustrates the "immediacy effect". The most recent literature has simply not yet had sufficient citable years to accumulate references, even though the sheer volume of new documents indicates that academic interest in digital teaching materials for critical thinking is currently at its peak.

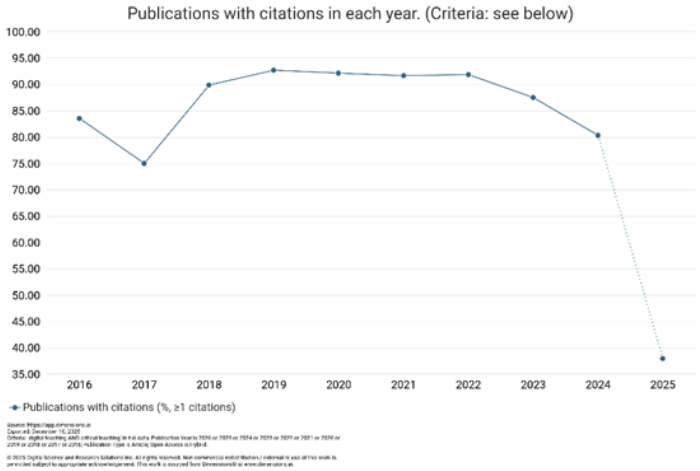

Figure 3. Publication with Citation from Dimensions Databases

According to Figure 3, it can be seen that the citation analysis reveals a significant inverse relationship between publication volume and individual article impact over the surveyed decade. While the number of citable documents (N) reached its zenith in 2025 with 32 publications, the highest scholarly impact was recorded in 2019, where a modest output of five documents achieved a peak Mean Total Citations per Article of 30.20. This suggests that the foundational research established during the field's earlier stages (2018–2021) continues to drive the theoretical discourse, as evidenced by consistent mean citation counts above 6.00 during this period. Conversely, the most recent years exhibit a "citation lag"; for instance, 2025 shows the highest productivity but the lowest mean impact (0.91 citations per article), indicating that while the field is expanding rapidly, the newest literature has not yet had sufficient time to accrue significant academic attention.

This temporal latency is further substantiated by the percentage of publications receiving citations, which remained remarkably robust and stable between 90% and 93% from 2018 through 2022. This stability indicates a highly active research community where the vast majority of published work was immediately relevant and referenced. However, a precipitous decline is observed starting in 2023, dropping to approximately 80% in 2024 and further to roughly 38% in 2025. This downward trajectory does not imply a reduction in research quality, but rather reflects the natural immediacy effect in bibliometrics, where the surge in volume (N=16 in 2023 to N=32 in 2025) currently outpaces the speed at which these new digital teaching material studies can be integrated and cited within subsequent global scholarship.

RQ2: What characterizes the collaborative patterns among the most highly cited and influential authors currently working on digital teaching materials for enhancing critical thinking skills?

3.2 Authors and Co-authorship Network

3.2.1 Co-authorship among Authors

The co-authorship relationships among researchers were examined to elucidate the dynamics of collaboration within this field of study. For this bibliometric analysis, 'Co-authorship' was designated as the type of analysis, with 'Authors' serving as the unit of analysis. According to Scopus Databases, the co-authorship analysis reveals a highly fragmented and decentralized research landscape, characterized by the presence of small, isolated "research silos" rather than a unified global community. The network visualization identifies several distinct colored clusters (e.g., green, red, and blue), each representing independent teams of authors who collaborate exclusively within their own groups. Notably, these clusters are physically separated on the map with no interconnecting lines, which indicates a complete absence of cross-collaboration between the different research factions working on digital teaching materials and critical thinking. While certain individuals like F. Chesire, M. Kaseje, and S. Lewin act as central nodes within their respective teams—demonstrating strong internal collaborative links—the overall network density is remarkably low. This structural isolation suggests that while specialized knowledge is being produced within specific pedagogical or geographical pockets, the field currently lacks the "knowledge brokers" or inter-institutional partnerships necessary to synthesize these disparate findings into a cohesive global framework.

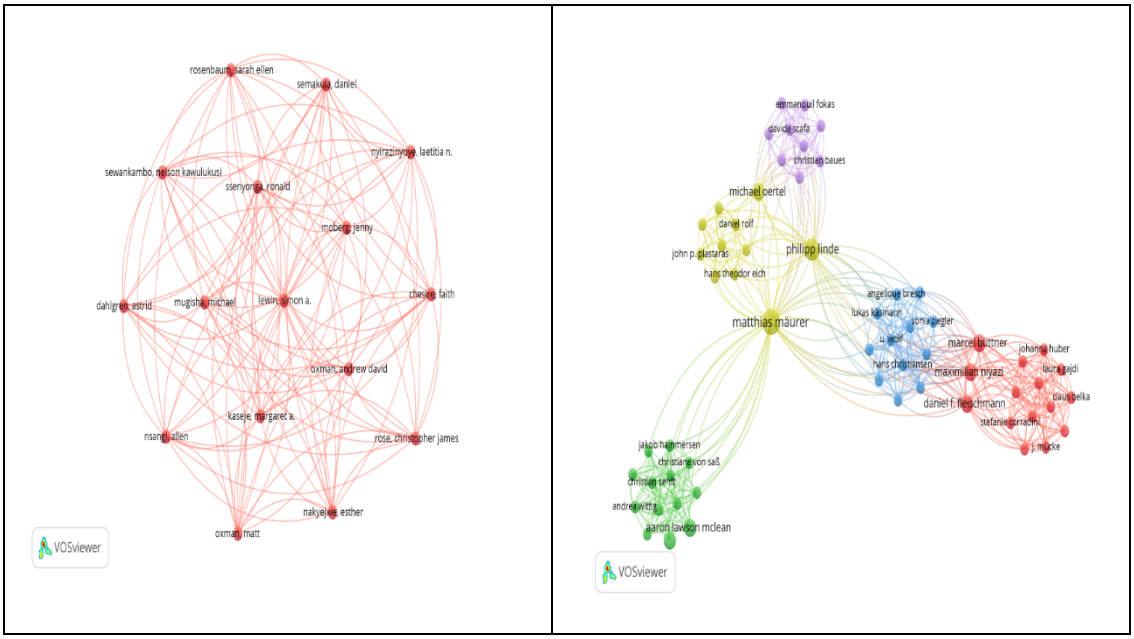

Figure 4. Co-Authorship Analysis of Authors (Scopus and Dimensions Databases)

According to Figure 4. the co-authorship network analysis from the Dimensions database reveals a highly collaborative and structured intellectual community, characterized by five distinct inter-connected clusters that signify a maturing field of research. Unlike the fragmented patterns often seen in emerging niches, this visualization demonstrates significant cross-cluster synergy, with Matthias Mäurer and Philipp Linde acting as pivotal "knowledge brokers" or

central nodes that bridge the yellow, green, blue, and purple research groups. The dense web of linkages within the red and blue clusters indicates intense localized collaboration, likely representing established institutional research laboratories or long-term international consortia dedicated to digital pedagogy. This structural integration suggests that the discourse on digital teaching materials for critical thinking has moved beyond isolated investigations into a more robust, networked phase where ideas are actively exchanged across different theoretical and geographical boundaries.

3.2.2 Co-Authorship among Countries

The analysis of country-level co-authorship within the Scopus database illustrates a global research network characterized by a high degree of international synergy, where Indonesia serves as the primary epicenter of scholarly collaboration. The visualization reveals a dense central cluster with Indonesia maintaining the most robust link strengths, indicating its pivotal role in bridging research between Eastern and Western academic spheres. This central hub is intricately connected to a diverse array of nations including the United States, the United Arab Emirates and South Africa, which form substantial nodes within the network, while countries like China, Norway, and Malaysia occupy more peripheral but stable positions. The emergence of multi-colored clusters linked through a network of lines indicates that the development of digital teaching materials for critical thinking has transcended isolated regional efforts, evolving instead into a globally integrated academic discourse. This transformation has been particularly propelled by Indonesia's substantial research output and its strategic role in fostering collaborative connections across diverse continents and varying levels of human development.

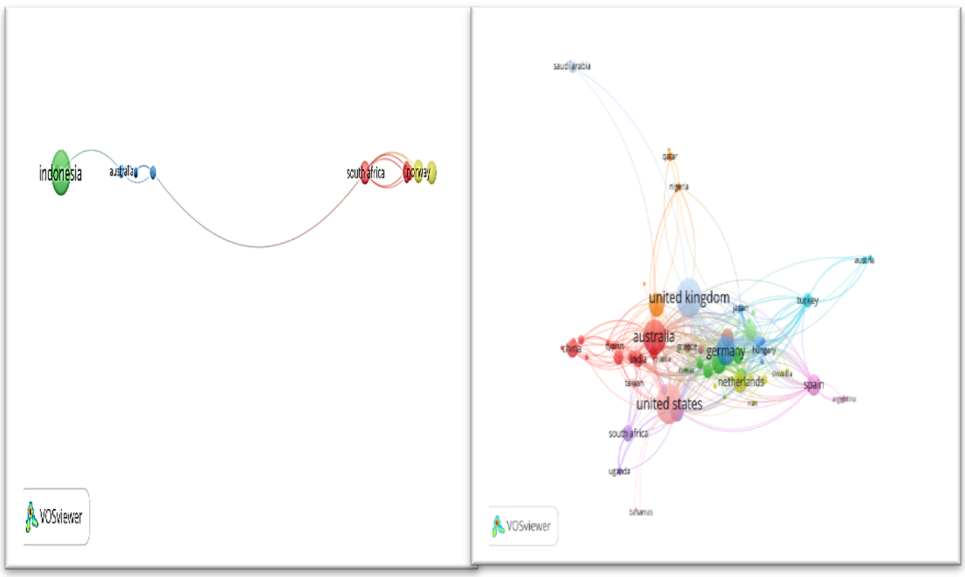

Figure 5. Co-Authorship Analysis of Countries (Scopus and Dimensions Databases)

Reffering Figure 4. shows that the country-level co-authorship analysis within the Dimensions database reveals a robust and highly integrated international research network, with the United Kingdom and the United States functioning as the primary global conduits for scholarly collaboration. The resulting network visualization depicts a complex configuration of interconnected nodes, in which the United Kingdom exhibits the highest Total Link Strength at 115, closely followed by the United States with a score of 112. This positions both countries as central mediators—or "knowledge brokers"—in the global discourse on digital instructional materials for critical thinking.

This network is characterized by three major collaborative clusters: a dominant Anglo-American and European cluster (red) including Australia, Germany, and Sweden; a focused Southern European group (green) led by Italy and Spain; and a distinct Asian-Pacific presence (blue and yellow) featuring Indonesia and Thailand. The high density of connecting lines across these clusters indicates that research in this field has transitioned from localized investigations into a mature, cross-border scientific discourse, where Western methodologies are increasingly being integrated with diverse global perspectives to address the challenges of 21st-century digital pedagogy.

RQ3: What are the research gaps and novelty in Digital Teaching Material For Improving Critical Thinking Skill for upcoming research?

3.3 The Research Gaps and Novelty by Neywork Approach-Thematic Map

The presence of "artificial intelligence" and "challenges" in this same quadrant indicates that the integration of smart technologies currently serves as a primary driver in the evolution of digital pedagogy aimed at sharpening critical reasoning. Meanwhile, topics such as "game-based learning," "collaborative learning," and "critical thinking skills" (plural) are situated in the emerging or declining themes quadrant, suggesting a need for research reorientation or the growth of new specializations outside conventional frameworks. Conversely, "augmented reality" is positioned as a basic theme, implying that while it constitutes an essential technical foundation for the field, it requires further exploration to achieve conceptual maturity as a primary instrument for future instructional strategies.

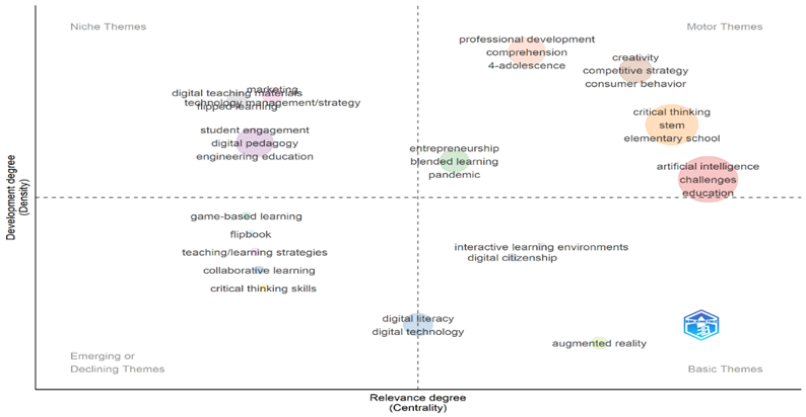

Figure 6. Thematic Map in Digital Teaching Material For Improving Critical Thinking Skill

The figure 7. shows that thematic map reveals a dynamic intellectual structure within the literature, where "critical thinking," "STEM," and "elementary school" emerge as established motor themes, signifying both high relevance and strong internal development within the context of primary education. Despite the maturation of "critical thinking" and "STEM" as central pedagogical drivers in "elementary school" settings, a significant gap remains where specialized "niche themes"—specifically "flipped learning" and "digital teaching materials"—operate in isolation from established "motor themes". While "artificial intelligence" is rapidly emerging as a transformative "challenge" within the global educational landscape, current scholarship has yet to fully integrate "game-based" and "collaborative learning" strategies with the technical foundations of "augmented reality" to create a cohesive instructional framework.

Furthermore, although "professional development" is a well-developed area of research, there is a lack of empirical evidence exploring how "digital pedagogy" can be transitioned from a specialized niche into a mainstream "instructional strategy" that effectively balances "21st-century skills" with student "comprehension". Consequently, there is an urgent need for research that bridges these disparate thematic clusters to provide a unified, technology-mediated approach for fostering critical reasoning in the next generation of learners.

4. Discussion

4.1 The Annual Trends In Digital Teaching Material For Improving Critical Thinking Skill Based On Publication And Citation Per Year 2015-2025

Publication trends between 2016 and 2025 reveal a significant paradigm shift in the digitalization of education, with the Dimensions database recording a document volume that far outstrips Scopus, peaking in 2025. This phenomenon reflects the democratization of digital teaching material research, which is no longer confined to elite journals but has expanded into open-access platforms. Consistent with the observations of Haleem et al. [17] in the context of smart learning environments, the incorporation of digital tools has transitioned from a supplementary option to an indispensable prerequisite for cultivating 21st-century competencies in the post-pandemic era.

This exponential growth confirms that digital teaching materials have become mainstream in global pedagogical discourse. By incorporating tools such as artificial intelligence, augmented and virtual reality (AR/VR), and adaptive learning platforms, digital technologies facilitate more interactive, individualized, and flexible approaches to education. [18] [19]. These digital tools promote independent learning and offer convenient access to information, thereby cultivating essential 21st-century competencies such as creativity, critical thinking, collaboration, and communication. [20] [21]

4.2 The Characterizes Collaborative Patterns among The Most Highly Cited and Influential Authors Currently Working on Digital Teaching Materials for Enhancing Critical Thinking Skills

The co-authorship structure reinforces this fragmentation, as Scopus visualizations show isolated small groups, while Dimensions displays a more integrated network through central figures like Matthias Mäurer. The existence of these "knowledge brokers" is vital for bridging disparate theoretical perspectives. As explained by Arcos-argudo et al., [22],

"small-world" networks in educational research accelerate the validation of new pedagogical models; thus, integration among global researchers is an absolute prerequisite for achieving scientific consensus on the effectiveness of digital media in sharpening student logic.

The integration of educational technology encompasses the deliberate application of digital tools to enhance learning, including the cultivation of critical thinking abilities. Influential authors collaborate on projects that focus on effective technology integration, creating digital teaching materials that enhance educational outcomes. This concept is directly relevant to understanding the collaborative efforts in digital teaching material development. The primary challenge for educators lies in determining the most effective methods for teaching with technology while simultaneously advancing their students' technological proficiency. In the United States, federal legislation currently mandates the integration of technology into school curricula, driven by the widespread belief that its use enhances learning outcomes. [23].

The incorporation of gamification strategies in educational settings involves leveraging game mechanics to foster more engaging learning environments and to promote the development of critical thinking abilities. Collaborations among authors often focus on the integration of gamification strategies into digital teaching materials, making learning more engaging and interactive. This concept is relevant to the query as it highlights innovative approaches to digital education. The objective of this research is to conduct a critical review of the shortcomings and scholarly criticisms of gamification in education, focusing specifically on the risks of excessive simplification, the role of game-induced pleasure, and the effects on learner motivation, in order to shed light on how current engagement frameworks might be refined. [24]. Despite its growing popularity in educational settings, this review reveals that: (i) there is a lack of robust evidence supporting the enduring educational benefits of gamification; (ii) the practical application of gamified learning has outpaced theoretical understanding of its operational mechanisms; and (iii) knowledge regarding the contextualization of gamification approaches according to specific pedagogical environments remains limited, underscoring a gap between theoretical potential and practical application. [25].

Open educational resources (OER) are freely accessible, adaptable, and shareable educational materials. Collaborative efforts between authors often emphasize the creation and distribution of OER for critical thinking development, contributing to greater educational equity and accessibility.The nature of these collaborations highlights the commitment to making high-quality educational resources available to all. Subsequently, we outline a set of principles for developing thinking skills, underscoring the significance of mapping techniques in organizing knowledge. In the concluding section, we address critical considerations for cultivating critical and creative thinking through the integration of open educational resources and knowledge mapping strategies. [26].

4.3 The Research Gaps And Novelty In Digital Teaching Material For Improving Critical Thinking Skill For Upcoming Research

The presence of isolated niche themes such as "flipped learning" and "student engagement" points toward untapped future research opportunities. This gap suggests that although innovative learning strategies have been developed, their technical integration

with AI-based digital teaching materials has not yet been fully empirically tested in enhancing critical thinking skills. Future research must bridge basic themes like "augmented reality" with collaborative strategies to create a learning ecosystem that is not only interactive but also capable of systematically fostering critical capacities.

Augmented reality (AR) can be integrated into digital teaching materials to create immersive and interactive learning experiences. Augmented reality has the potential to foster critical thinking by offering students immersive, experiential learning opportunities that replicate authentic, real-world contexts. Investigating the effects of AR on critical thinking skills may reveal novel pedagogical approaches. A substantial body of research indicates that integrating AR into learning environments promotes critical thinking, deepens comprehension, and enhances learner motivation for continued study. [27]. When combined with pedagogical material, augmented reality technology produces innovative automated tools that significantly improve the efficacy and engagement of educational experiences within real-life settings. [28]. As an educational platform, augmented reality is progressively more attainable for young students, spanning both elementary and high school populations. Although existing studies suggest that AR technologies can positively influence learning, the field has yet to establish a clear understanding of their educational utility or to identify the particular circumstances under which this medium outperforms traditional or other digital learning tools. [29].

As digital teaching materials become more prevalent, ethical considerations regarding access, privacy, and bias must be addressed. Ensuring that digital materials are designed and implemented ethically is crucial for promoting fair and inclusive learning environments that support critical thinking development for all students. Virtual reality constitutes a valuable pedagogical resource for fostering critical thinking, as it enables immersive engagement with authentic, simulated contexts. By exploring how VR can be integrated with digital teaching materials, researchers can identify new avenues for creating engaging and effective learning experiences. Although the long-term educational implications of emerging technologies in this field are still uncertain, this is a question that demands the attention of those involved in educational research, teaching, and administration.[30].

5. Conclusion

The bibliometric analysis conducted from 2016 to 2026 demonstrates an exponential surge in global interest regarding digital teaching materials designed to enhance critical thinking, particularly following the pedagogical shifts of 2020. While the Dimensions database reveals a massive proliferation of scholarship—reaching its peak productivity in 2025—the citation impact remains anchored in seminal works from 2019, highlighting a temporal lag between the current volume of publication and the maturation of scholarly influence. Geographically, the field exhibits a unique dual-center dynamic: Indonesia emerges as a primary epicenter for productivity and collaborative bridging in Scopus, whereas the United States and the United Kingdom continue to serve as the dominant knowledge brokers in terms of citation impact and network strength.

Thematic mapping identifies a shift from traditional pedagogical frameworks toward an AI-driven information ecosystem, with "artificial intelligence" and "STEM" establishing themselves as transformative drivers for adaptive learning in elementary education. However, the research landscape remains notably fragmented, characterized by isolated "research silos" that lack the inter-institutional synergy required to synthesize disparate findings into a cohesive global framework. While "critical thinking" is now a consolidated global policy priority, the integration of niche technologies such as augmented reality and flipped learning into mainstream instructional strategies is still in its nascent stages, requiring more robust empirical validation.

This study thus furnishes a practical roadmap for educational stakeholders seeking to effectively manage the evolving demands of digital-era pedagogy. The findings underscore an urgent need for cross-border collaboration and a thematic reorientation that bridges the gap between technical foundations and higher-order thinking dispositions. To ensure the effectiveness of technology-mediated materials, future research must move beyond localized investigations toward a unified approach that balances digital innovation with the fundamental goal of fostering inquisitive, analytical, and open-minded learners in an increasingly automated world.

References

[1] M. P. Arthi and S. N. S. Gandhimathi, “Heliyon Research trends and network approach of critical thinking skills in English Language Teaching – A bibliometric analysis implementing R studio,” *Heliyon*, vol. 11, no. 2, p. e42080, 2025, doi: 10.1016/j.heliyon.2025.e42080.

[2] A. S. Cantillo-orozco and J. L. Castillo-loaiza, “European Journal of Educational Research,” vol. 15, no. 1, pp. 19–38, 2026.

[3] M. M. Sakthivel, S., Aruldoss, L., Vinoth, M., & Bharathi, “The Impact of Digital Storytelling on Motivation ,” in *AIP Conf. Proc. 3270, 020232 (2025)*, 2025. doi: 10.1063/5.0261869.

[4] A. Meirbekov, I. Maslova, and Z. Gallyamova, “Digital education tools for critical thinking development,” *Think. Ski. Creat.*, vol. 44, no. March, p. 101023, 2022, doi: 10.1016/j.tsc.2022.101023.

[5] I. Passas, “Bibliometric Analysis : The Main Steps,” pp. 1014–1025, 2024.

[6] A. I. Akbar and E. Raffasya, “Development of Inquiry Learning-Based Digital Teaching Materials to Enhance Critical Thinking Skills,” vol. 03, no. 02, pp. 80–89, 2025.

[7] L. Ran, “Enhancing specific critical thinking skills among EFL learners through computer-assisted interactive reading model in a CALL environment : An investigation of learner perceptions and performance,” vol. 58, no. July 2024, pp. 1–19, 2025.

[8] B. Hassan, M. O. Raza, Y. Siddiqi, M. F. Wasiq, and R. A. Siddiqui, “CONNECT : An AI-Powered Solution for Student Authentication and Engagement in Cross-Cultural Digital Learning Environments,” pp. 1–14, 2025.

[9] T. Soe, “Investigating Critical Thinking in ELT Textbooks : A Systematic Literature Review of Textbook Evaluation Studies Critical Thinking Integration in ELT Textbooks,”

vol. 10, no. 1, pp. 1–29, 2024.
[10] M. M. Ndahimana and P. Nkundabakura, “Lower Secondary Mathematics and Science Teachers’ Perceptions Towards Project-Based Learning in Rwanda,” *African J. Educ. Stud. Math. Sci.*, vol. 19, no. 2, pp. 233–240, 2023.
[11] M. T. Hebebci, “The Bibliometric Analysis of Studies on Distance Education,” *Int. J. Technol. Educ.*, vol. 4, no. 4, pp. 796–817, 2021, doi: 10.46328/ijte.199.
[12] R. Miskiewicz, “Internet of Things in Marketing: Bibliometric Analysis. Marketing and Management of Innovations,” *Mark. Manag. Innov.* , vol. 3, no. 3, pp. 371–381, 2020, [Online]. Available: http://doi.org/10.21272/mmi.2020.3-27
[13] T. Talan, “Augmented Reality in STEM Education: Bibliometric Analysis,” *Int. J. Innov. Res. Arts, Educ. Technol.*, vol. 3, no. 1, pp. 63–71, 2025, doi: 10.48028/iiprds/ijiraet.v3.i1.07.
[14] M. Gutiérrez-Salcedo, M. Á. Martínez, J. A. Moral-Munoz, E. Herrera-Viedma, and M. J. Cobo, “Some bibliometric procedures for analyzing and evaluating research fields,” *Appl. Intell.*, vol. 48, no. 5, pp. 1275–1287, 2018, doi: 10.1007/s10489-017-1105-y.
[15] W. Hewer, F. Jacobi, and F. Schneider, “Physical health in people with severe mental illness,” *Nervenarzt*, vol. 96, no. 2, pp. 203–213, 2025, doi: 10.1007/s00115-025-01802-0.
[16] A. P. Rovai and H. M. Jordan, “Blended learning and sense of community: A comparative analysis with traditional and fully online graduate courses,” *Int. Rev. Res. Open Distance Learn.*, vol. 5, no. 2, 2004, doi: 10.19173/irrodl.v5i2.192.
[17] A. Haleem, M. Javaid, M. Asim, and R. Suman, “Understanding the role of digital technologies in education : A review,” *Sustain. Oper. Comput.*, vol. 3, no. February, pp. 275–285, 2022, doi: 10.1016/j.susoc.2022.05.004.
[18] A. I. Stoumpos, “Modern Digital and Technological Educational Methods,” *Trends High. Educ.*, pp. 1–30, 2025.
[19] N. N. Pluzhnikova, “Innovative uses of digital technologies in teaching humanities in higher education,” in *AIP Conf. Proc. 3268, 060022 (2025)*, AIP Publishing LLC., 2025. doi: https://doi.org/10.1063/5.0257152.
[20] T. Howard and M. Rohs, “Digitization bolstering self-directed learning for information literate adults – A systematic review,” *Comput. Educ. Open*, vol. 2, p. 100048, 2021, doi: 10.1016/j.caeo.2021.100048.
[21] H. Yoo, “Building 21st Century Skills Through Technology in General Music Classes,” 2022, doi: 10.1177/27527646221110867.
[22] M. Arcos-argudo, F. Pesántez-avilés, and D. Peñaloza-rivera, “Small World Networks in Education Sciences,” in *In International Conference on Applied Human Factors and Ergonomics (pp. 66-75).*, Cham: Springer International Publishing., 2018. doi: 10.1007/978-3-319-93882-0_7.
[23] B. R. S. Davies, “Understanding Technology Literacy : A Framework for Evaluating Educational Technology Integration,” no. October, 2011.
[24] D. H. T. Chee, C. M., & Wong, “Affluent Gaming Experience Could Fail Gamification in Education: A Review,” *ETE Tech. Rev.*, vol. 34, no. 6, pp. 593–597, 2017.
[25] C. Dichev and D. Dicheva, *Gamifying education : what is known , what is believed and what remains uncertain : a critical review*. 2017. doi: 10.1186/s41239-017-0042-5.
[26] A. Okada, “Using knowledge maps applied to open learning to foster thinking skills,” 2007.
[27] M. K. Gupta, N., & Rohil, “Exploring possible applications of augmented reality in

education," in *In 2017 4th International Conference on Signal Processing and Integrated Networks (SPIN)*, IEEE, 2017, pp. 437–441.
[28] M. Kesim and Y. Ozarslan, "Augmented reality in education : current technologies and the potential for education," *Procedia - Soc. Behav. Sci.*, vol. 47, no. 222, pp. 297–302, 2012, doi: 10.1016/j.sbspro.2012.06.654.
[29] J. Article and I. Radu, "Augmented reality in education : a meta-review and cross-media analysis — Source link," 2014, doi: 10.1007/S00779-013-0747-Y.
[30] P. E. Connolly, "Virtual Reality & Immersive Technology in Education," *Int. J. Inf. Commun. Technol. Educ.*, vol. 1, no. 1, pp. 12–18, 2005.