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The Role of Learning Technology in Critical Thinking Skills: A Bibliometric Analysis of Current Trends and Future Research Directions

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Review Article

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Abstract

Background/purpose. In the digital era, learning technology plays a crucial role in fostering 21st-century skills such as critical thinking. Despite many studies on technology in education, comprehensive analyses of global research trends on learning technology for critical thinking skills (LTCTS) remain limited. This study addresses the gap through a bibliometric analysis that maps patterns, key contributors, thematic developments, and future research directions.

Materials/methods. This study employed bibliometric analysis using 1,118 Scopus-indexed journal articles published between 2005 and 2025. Data were collected using targeted keywords and filtered by document type, language, and publication stage. The dataset was cleaned with OpenRefine and analyzed using VOSviewer, Biblioshiny (Bibliometrix R package), and Microsoft Excel.

Results. Findings reveal a consistent growth in LTCTS publications, with a sharp increase since 2017. The USA, China, and Indonesia emerged as the most productive countries, while Indonesia dominated in top-affiliating institutions. Key research themes have evolved from e-learning and pedagogical issues to AI-driven learning systems, federated learning, and immersive technologies. Ethical considerations in AI and domain-specific applications, such as medical and science education, are identified as emerging areas.

Conclusion. LTCTS research has experienced rapid expansion, reflecting global recognition of its importance in modern education. Future studies should explore emerging technologies, ethical AI integration, and interdisciplinary applications while strengthening international collaboration. This study provides a comprehensive foundation for guiding research, policy, and practice in leveraging technology to enhance critical thinking skills.

1. Introduction

In the middle of a rapidly evolving digital era, learning technology plays a key role in the modern education system. With the onset of the Industrial Revolution 4.0 and the emergence of Society 5.0, the inclusion of ICT and the use of mobile learning (m-learning) have become crucial in educational institutions (Fitriati et al., 2025; Weeden & Cornwell, 2020). Digital transformation has created new opportunities for individuals to obtain knowledge and engage in the learning process (Alenezi, 2023; de Bem Machado et al., 2022; Mohamed Hashim et al., 2022). Advances in learning technology, including e-learning, interactive educational applications, and the integration of artificial intelligence in education, offer significant potential to improve the effectiveness and efficiency of learning. Along with the development of digital platforms, teachers can utilize various resources and tools to improve learning outcomes and motivation in various ways, depending on the context and specific learning needs. One of the most essential learning outcomes in this era is the cultivation of 21st-century skills, such as critical thinking skills.

Critical thinking skills are becoming increasingly important to develop in students at all levels, from elementary school to higher education. Furthermore, the ability to critically assess information, recognise valid arguments, and solve problems is an essential skill not only in educational settings but also in the workplace and daily life (Dare et al., 2021; García-Pérez et al., 2021). Researchers have made many efforts to improve critical thinking skills, and the use of technology has emerged as a major concern. Social Cognitive Theory (Bandura, 1986) posits that behaviour, cognition, and emotions are shaped by the surrounding environment, including the technology humans engage with (Bhatt et al., 2023; Fabio & Suriano, 2021; Suriano et al., 2025; Xu et al., 2023). Numerous studies have shown the influence of technology on cognitive processes, such as memory, executive abilities, attention, and reasoning (Amez & Baert, 2020; Meltzer et al., 2023; Song et al., 2025). Through various digital tools and platforms, students are not only given access to information but also involved in activities that stimulate their analytical and problem-solving abilities. For example, the use of simulations, online discussions, and technology-based data processing can help students think more critically about the problems they face and devise more innovative solutions.

Technology plays a broad role in education, including in improving critical thinking skills, as evidenced by empirical studies. Empirical research indicates that technology significantly enhances various aspects of critical thinking, such as evaluating arguments and information, understanding and using graphs and basic mathematics, drawing logical conclusions, and asking or answering clarifying questions (Ennis, 2011; Facione, 2011). With the rapid development of technology, the ability to access diverse and evolving information is vital for training students to be more critical when evaluating arguments and information, because not all of the information they obtain is valid (Jabarian & Sartori, 2024; Pilgrim et al., 2019; van Zyl et al., 2020) in the context of knowledge related to data that is often modeled mathematically and represented in various ways (e.g., visual, graphical, or tabular). The use of technology that supports the visualization process will be useful for training students to understand basic mathematics and graphs, for example, Mathematica (Nizaruddin et al., 2022) and Microsoft Excel (David & Brown, 2012; Joseph & Ridwan, 2024). Furthermore, the widespread use of technology in online and blended learning, such as Massive Open Online Courses (MOOCs), Google Classroom, and Moodle, is increasingly used for material-based learning, which can empirically improve critical thinking skills (DuBois et al., 2019; Williams, 2024). The use of technology in distance learning also makes it easier for students to collaborate and exchange ideas, thereby encouraging more effective critical thinking (Maphosa, 2024).

Research on learning technology and the development of critical thinking skills has made significant progress in recent years. Various studies have revealed how technology can improve interaction (between students, students-teachers, and students-environment) (Marks & Thomas, 2022; Beldarrain, 2007), support collaboration between students (Kim et al., 2022; Mok, 2021), and

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provide opportunities for students to develop critical thinking skills (Gonzalez-Mohino et al., 2023; Meirbekov et al., 2022). However, despite the broad interest in the intersection of technology and critical thinking, gaps remain in understanding the specific mechanisms through which various technologies directly influence critical thinking skills at different levels of education. Some previous studies have focused more on specific technologies or specific aspects of learning, while the comprehensive role of technology in enhancing critical thinking remains underexplored. Therefore, bibliometric analysis is important to explore existing research trends in this field.

Bibliometric analysis enables the identification of research patterns, examination of topic development, mapping of influential authors, institutions, and countries along with their collaborations, analysis of citations and references, and the identification of gaps in the current literature (Irwanto, 2025; Salim et al., 2025; Widyaningsih et al., 2025). This analysis enhances our understanding of advances in research on learning technologies and critical thinking skills, while also pinpointing areas that require further investigation. A bibliometric analysis concerning critical thinking skills and the application of learning technology has been performed before. Critical thinking skills have been focused on certain disciplines, such as science education (Misbah et al., 2022), Physics (Aisah et al., 2024; Jatmiko et al., 2021), physical education (Ridwan et al., 2022), and EFL (Arthi & Gandhimathi, 2025; Yücel, 2025). On the other hand, some researchers focus on critical thinking research trends at certain levels of education, such as early childhood (Ergin & Temel, 2023), Primary (Aktoprak & Hursen, 2022), and higher education (Nuryana et al., 2024). Although these studies are valuable, previous bibliometric analyses have limitations, namely that they focus only on specific disciplines, educational levels, or technologies. No bibliometric analysis has comprehensively addressed how learning technology affects critical thinking skills. This paper plays an important role in filling this scientific gap by mapping the development of research on efforts to improve critical thinking skills from the perspective of learning technology use. By expanding the scope to include various disciplines and education levels, the findings presented are more comprehensive. Therefore, in exploring research trends on the role of learning technology in critical thinking skills (LTCTS), this article will answer several questions, including.

RQ1. What is the main information about the research trends of LTCTS?

RQ2. What are the trends in publications on the role of LTCTS?

RQ3. Which authors, affiliations, and countries have made the most significant contributions to research on the role of LTCTS?

RQ4. What is the most relevant word about the role of LTCTS?

RQ5. What will be the focus of future research on the role of LTCTS?

2. Literature Review

2.1. Learning Technology

Learning technology refers to the use of various tools, devices, and technological systems to support, facilitate, and enhance teaching, learning, and assessment (Stoner et al., 1996). Learning technology is continually being developed to address learning issues, enhance learning experiences, and achieve learning objectives. Learning technology encompasses a broad range of tools, including communication devices such as video conferencing and webinars, which facilitate real-time interactions between learners and educators (Ali et al., 2021; Criollo-C et al., 2021; Stošić & Bogdanović, 2013). It also involves interactive tools, such as interactive whiteboards and simulations, that actively engage learners in the learning process (Asad et al., 2020; Conceição, 2022). Additionally, information retrieval systems are designed to help learners access and acquire information efficiently (Musaev et al., 2024). Content distribution is facilitated through methods such

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as vodcasting and podcasting, which enable the dissemination of educational materials (Gardiakos et al., 2025; Vergara, 2022). Throughout history, tools such as blackboards, cassette tapes, and basic instructional aids have served as learning technologies that have since evolved into more sophisticated digital technologies. In recent developments, technologies such as Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI) are increasingly being utilized in educational settings. This study focuses on technologies such as artificial intelligence (AI)-based tools, online learning platforms, computer applications, and mobile applications, as these technologies are highly relevant in developing critical thinking skills.

2.2. Critical Thinking Skills

Critical thinking is considered one of the essential learning and innovation skills, as well as one of the competencies most frequently cited as crucial for academic and career success. It is believed to play a central role in logical thinking, decision-making, and problem-solving (Altun & Yildirim, 2023; O. L. Liu et al., 2014). However, a review of the literature reveals that, despite a general consensus on the importance and necessity of critical thinking, there is no agreement on its definition (Johnson & Hamby, 2015; Rademaekers & Detweiler, 2019; Thonney & Montgomery, 2019). Many references mention that critical thinking is a cognitive process that involves several skills. In this study, critical thinking is defined based on the perspectives of Ennis (2011) and Facione (2011), among the most widely adopted in various disciplines, emphasizing the ability to argue logically and systematically, to evaluate arguments, and to make decisions based on evidence. Critical thinking involves careful evaluation and analysis of information, arguments, and evidence, including synthesis, integration, and conceptualization of knowledge obtained through various means such as communication, observation, and experience (Papathanasiou et al., 2014; Verma et al., 2022). Logical reasoning is also necessary to draw conclusions or make decisions based on available evidence and observations (Dwyer et al., 2014; Vincent-Lancrin, 2023). Furthermore, critical thinking is often described as a metacognitive process, which means it involves reflective judgment that helps generate logical conclusions and solve problems effectively (Guamanga et al., 2025; S. Li et al., 2024; Rivas et al., 2022). On the other hand, problem solving and decision making, which are very important skills, involve separating facts from opinions, understanding and using basic graphical and mathematical information, evaluating the credibility of information sources, and clarifying concepts (Dawson et al., 2024; Ennis, 2018; van Zyl et al., 2020). Critical thinking is a practice that involves understanding and responding to experiences in the world, not just abstract thinking, but also situational critical engagement between individuals and texts. In educational practice, critical thinking skills are among the skills that need to be trained in students, even from an early age.

2.3. The Role of Learning Technology in Critical Thinking Skills

Technology plays an important role in developing critical thinking skills, supported by several factors. Technology can provide easy access to a variety of information that broadens perspectives, interactive learning tools that stimulate analysis and creativity, and remote collaboration that enables more flexible, in-depth discussion (Moustahfir & Brigui, 2024; Swart, 2017). The use of e-learning has been proven to significantly enhance critical thinking skills by offering an alternative approach to interacting with learning materials and collaborating with peers (Lebese & Mhlongo, 2024). Technology also plays a role in helping users verify facts (Juneja & Mitra, 2022), evaluate information sources (Nikou et al., 2022; Nikou & Aavakare, 2021), and use analytical tools to analyze data in depth (Kravchenko et al., 2023), thereby strengthening the ability to make logical and evidence-based decisions. Thus, technology not only enhances access to information but also facilitates the development of critical thinking skills more effectively.

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3. Methodology

3.1. Research Design

Bibliometric analysis is used to answer the questions in this paper. Bibliometric analysis is a qualitative and quantitative analysis that provides the latest information on research development trends in specific areas and guides readers in exploring potential future research opportunities (Yu & Li, 2022). This bibliometric analysis was used because of the large number of documents analyzed (Donthu et al., 2021). Initially, bibliometrics was used to assess academic productivity and the impact of a particular academic's or institution's work by counting the number of articles and citations produced (e.g., Lima & Bonetti, 2020). The use of bibliometrics is growing and is widely used by researchers from various countries to characterize the patterns and structures of research development in various areas based on the emergence of research variables/content (e.g., Ariyatun et al., 2024; Houlden et al., 2021; Turmuzi et al., 2024; Xiong et al., 2021). Therefore, we use bibliometric analysis to answer the questions in this paper.

3.2. Data Collection

The articles analyzed in this paper are from the Scopus database. The Scopus database was chosen because it spans multiple disciplines and provides the largest abstracts and citations, covering more sources than may not be available in WoS (Alsharif et al., 2020). Scopus ensures that only the highest quality data is included through a rigorous content selection process and periodic evaluations conducted by an Independent Content Selection and Advisory Board (Baas et al., 2020). Scopus provides easy data export in various file formats (CSV, RIS, BibTeX, and plain text), various reference managers (Rendeley, RefWorks, Zotero, and EndNote), and platforms (SciVal) that support bibliometric analysis.

We used the keywords “critical thinking*” AND “Technology-enhanced Learning” OR “E-learning” OR “learning media” OR “ICT in Education” OR “Information and Communication Technology” OR “Digital Learning” OR “Blended Learning” OR “virtual reality” OR “augmented reality” OR “artificial intelligence” OR “AI” in the Article title, Abstract, Keywords categories in the search engine of www.scopus.com. At the beginning of the search, 2,831 papers were obtained. Furthermore, we limited the papers to several criteria, namely, papers published in 2005-2025, document type: article, publication stage: final, source type: journal, and language: English, resulting in 1,118 articles for analysis. The data collection and screening process for the bibliometric analysis of the role of LTCTS is shown in Figure 1.

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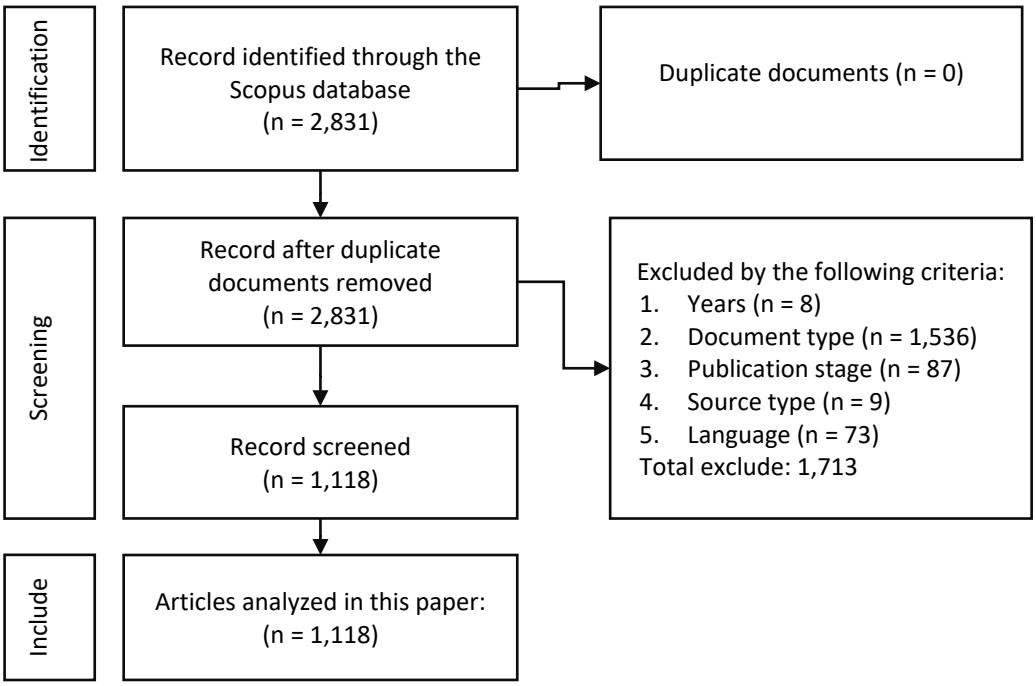

Figure 1. The Data Collection and Screening Process for The Bibliometric Analysis of The Role of LTCTS

To ensure the reliability and transparency of the analysis, we used the JBI checklist for Systematic Reviews (Aromataris et al., 2015). This checklist is applied by a team of three experienced researchers with doctoral qualifications, all of whom have significant expertise in conducting and publishing systematic literature reviews (SLRs). The use of this checklist ensures that the systematic review process follows best practices and helps reduce potential bias, resulting in a comprehensive review that adheres to strict academic standards.

3.3. Data Analysis

The data we obtained from the Scopus database is in CSV format. We obtained this data on March 13, 2025. Before analyzing the data, we cleaned it in OpenRefine. This step involved standardizing keywords that were identified as variations of the same term. For example, we merged “student” and “students” to ensure consistency across the dataset. This was done using custom clustering algorithms in OpenRefine to group similar terms. After screening the data, we used VOSviewer to visualize the international collaboration network and the network connecting keywords. Additionally, we used Biblioshiny (Bibliometrix R tool) for a more in-depth bibliometric analysis, including the main information, data on publication counts per year, citation data per year, identification of the most relevant authors, author impact data, most relevant affiliations and their productivity, leading contributor countries, thematic evolution, and trends in research topics. This tool provided comprehensive insights into the research patterns and trends. For better readability and to display specific data points, such as publication counts per year, we also used MS Excel to visualize them.

4. Results

We will discuss the results of a bibliometric analysis of the role of LTCTS, based on pre-established questions and supported by relevant information. Linking findings to existing knowledge can yield new insights into closely related research topics.

4.1. Main Information about the Research Trends of LTCTS (RQ1)

The main information (Table 1) provides an overview of all the articles analyzed. Based on 1,118 articles on learning technology and critical thinking skills published from 2005 to 2025, this research area has received significant attention, with an annual growth rate of 15.55% and an average citation per article of 16.48. The total of 9,863 references across all documents reflects the depth and diversity of the literature used, indicating the quality and complexity of the research in this field. The substantial number of references also highlights the close interconnections among the existing studies. It is important to note that, although 9,863 references are cited across 1,118 documents, this does not imply an average of approximately 9 references per document. Biblioshiny is designed to count unique references, meaning that a single reference cited by multiple documents is counted as one reference.

The higher number of Author's Keywords compared to Keywords Plus indicates a greater diversity of research foci, while the uniqueness of keywords reflects the degree of disciplinary diversification. In the case of LTCTS research, the presence of a substantial number of unique keywords indicates the breadth of sub-topics associated with LTCTS, suggesting considerable potential for future expansion and development. This research area also involves good collaboration between researchers. This is indicated by the relatively low number of articles written by a single author —212 (18.96%). In addition, the average number of co-authors per article is 3.47, and articles involving collaboration between countries account for 19.5%. Furthermore, we will discuss our findings more specifically in the next section.

Table 1. Main Information on Biblioshiny Analysis Results

Description	Results
Main Information About Data	
Timespan	2005:2025
Sources (Journals, Books, etc.)	577
Documents	1,118
Annual Growth Rate %	15.55
Document Average Age	4.03
Average citations per doc	16.48
References	9,863
Document Contents	
Keywords Plus (ID)	2,649
Author's Keywords (DE)	3,038
Authors	
Authors	3,604
Authors of single-authored docs	205
Authors Collaboration	
Single-authored docs	212
Co-Authors per Doc	3.47
International co-authorships %	19.5
Document Types	
article	1,118

4.2. Publications Trends on the Role of LTCTS (RQ2)

In the period from 2005 to 2025, the role of learning technology in developing critical thinking skills has attracted significant attention from researchers. In this section, we discuss publication trends related to this topic, identifying patterns of growing researcher interest based on the number

of publications and citations over the past two decades. Figure 2 shows the change in the number of publications on the role of LTCTS from 2005 to 2025. The data shows a fairly fluctuating change in numbers, especially in the first decade. At the beginning of the period (2005-2016), the number of articles published was relatively low, ranging from 2 to 23 per year and fluctuating significantly. However, since 2017, there has been a sharp increase, reaching 340 articles in 2024, indicating growing interest in this topic. On the other hand, the decrease in publications from 2024 to 90 in 2025 is due to data collection at the beginning of the year (March 13, 2025), so the number of publications in this area will continue to grow throughout the year. In general, this trend indicates that the subject is becoming a more significant focus of research in educational technology and in the development of critical thinking skills. The growing research interest in this area is evidenced by the surge in publications. Rapid technological progress and greater recognition of the importance of critical thinking in the digital age are drawing more attention from researchers.

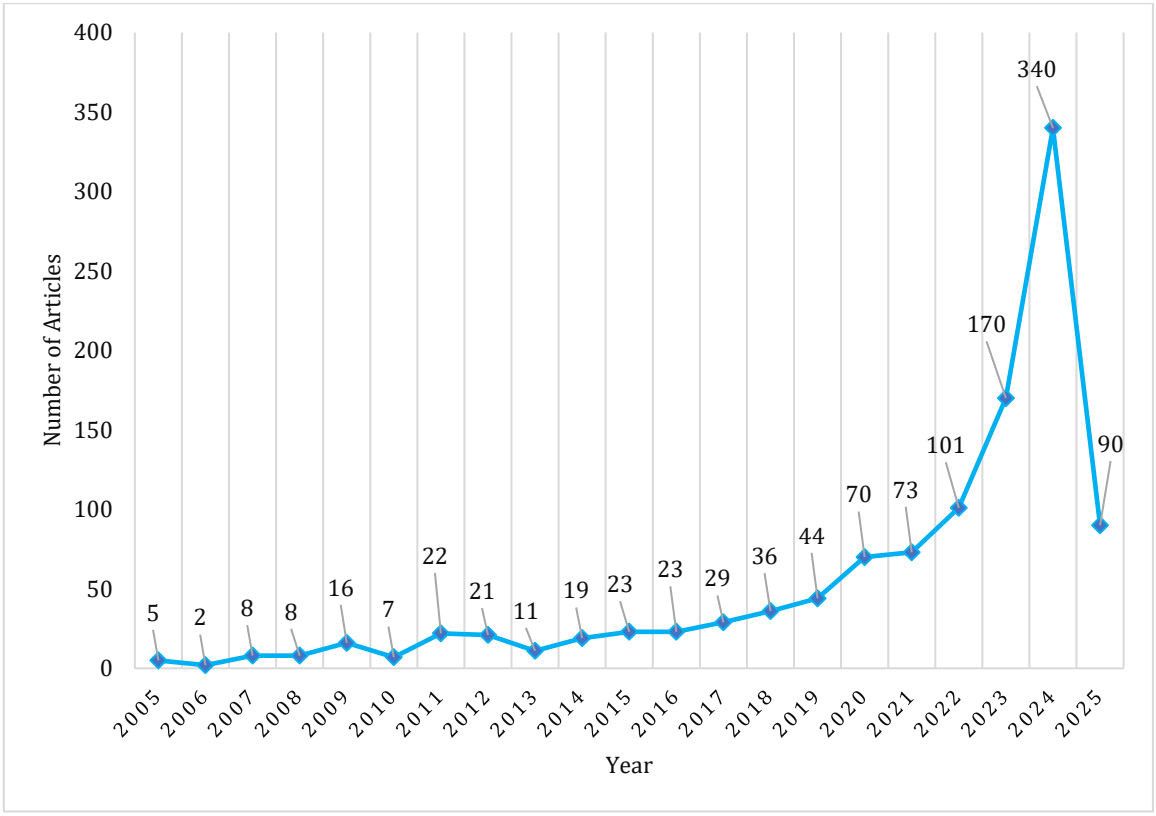

Figure 2. The Change in The Number of Publications

Information on citations in articles is shown in Table 2. Overall, the number of citations in articles relating to the role of LTCTS is quite high. The highest average total citations per article occurred in 2009, at 62.31 citations across 16 articles. This year, articles received an average of 3.67 citations per year, with 17 citable years. On the other hand, in 2006, the two articles received an average of 2 citations per article, for a total of 0.10 citations per year. This is due to the articles' low relevance to the research areas in which most researchers work. However, the 90 articles published in 2025 have already received an average of 0.67 citations per article. This shows that some articles are relevant to articles published in the same year. The data in Table 2 can generally help researchers explore in-depth areas of research in high demand, as indicated by the number of citations.

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Table 2. Data on the Citation Counts of Published Articles

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2005	32.40	5	1.54	21
2006	2.00	2	0.10	20
2007	50.25	8	2.64	19
2008	29.25	8	1.62	18
2009	62.31	16	3.67	17
2010	23.00	7	1.44	16
2011	27.73	22	1.85	15
2012	28.57	21	2.04	14
2013	39.27	11	3.02	13
2014	41.95	19	3.50	12
2015	34.35	23	3.12	11
2016	33.96	23	3.40	10
2017	19.97	29	2.22	9
2018	20.19	36	2.52	8
2019	17.43	44	2.49	7
2020	24.17	70	4.03	6
2021	15.75	73	3.15	5
2022	10.11	101	2.53	4
2023	29.49	170	9.83	3
2024	4.24	340	2.12	2
2025	0.67	90	0.67	1

4.3. Leading Contributors: Authors, Affiliations, and Countries (RQ3)

In this sub-discussion, the main contributors to research on the role of learning technology in critical thinking skills will be identified. Emphasis will be placed on notable writers, their institutional affiliations, and countries that substantially contribute to the advancement of this subject in scientific literature.

4.3.1. Authors Leading Contributors

Figure 3 illustrates the variation in contributions among the leading authors in the study of the role of learning technology on critical thinking skills. Hwang GJ stands out as the primary contributor, with 13 publications, the most of any author. This suggests that Hwang GJ may have conducted a comprehensive body of research or possesses considerable expertise in this domain, leading to frequent citations of his work by other scholars (Table 3).

The influence of an author within a specific research area is determined not only by the number of published papers in reputable journals but also by citation-based metrics such as the h-index, g-index, and m-index. The H-index reflects the balance between productivity and citation impact,

indicating that an author has received at least h citations for h published documents. The g-index, in contrast, gives greater weight to highly cited papers, capturing the overall citation performance of an author's most influential works. Meanwhile, the m-index adjusts the h-index based on the number of years since the author's first publication, thereby providing an indicator of the consistency and sustainability of scholarly impact over time.

As shown in Table 3, Hwang GJ has accumulated 673 citations since 2011, with an h-index of 9, a g-index of 13, and an m-index of 0.6. On the other hand, Chang CY has created 6 documents, indicating a significant contribution, although not as great as Hwang GJ, who has received 230 citations since 2018. This indicates that, despite a limited number of documents and a more recent publication year than Hwang GJ, Chang CY has had a significant impact on this area of research. Overall, the data in Figure 3 and Table 3 show that, although many authors are involved, no author dominates publications on this topic. Of the 3,604 total authors who published 1,118 articles in this research area, the most productive and influential authors accounted for only 13 articles (0.36%) of the total. However, this actually shows a positive academic atmosphere, where a research area is actively engaged by many researchers from various countries, without being dominated by any single author.

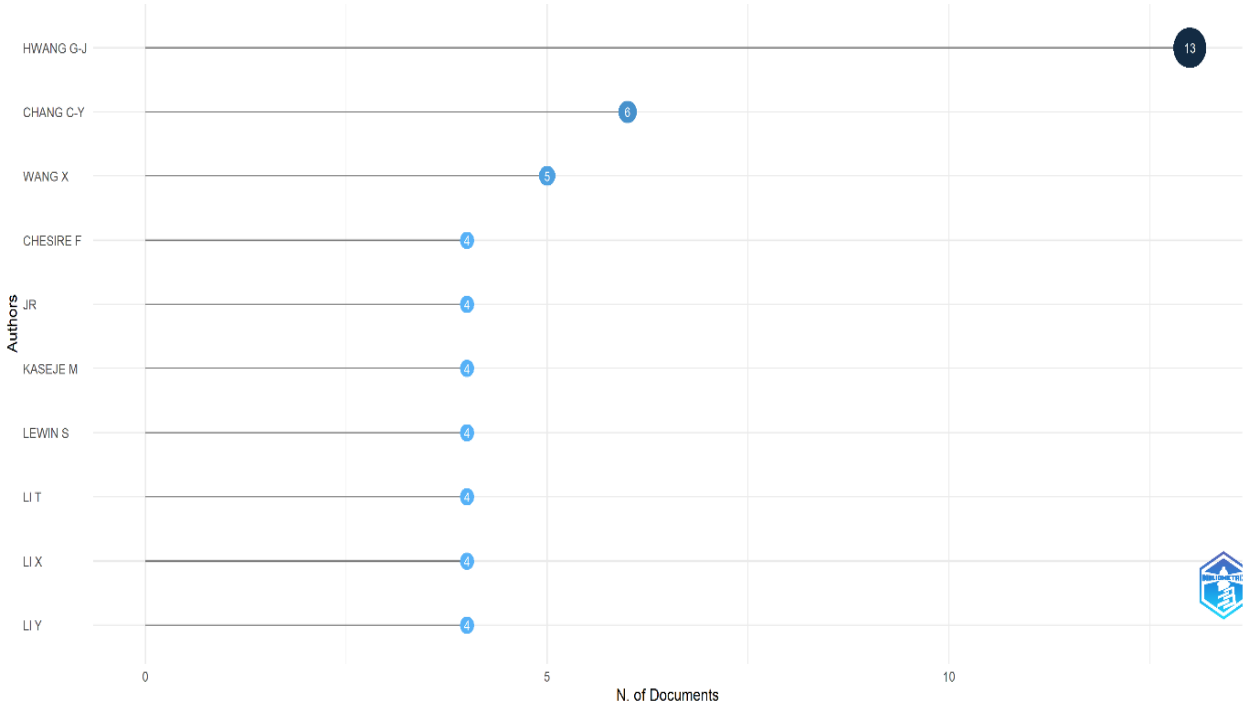

Figure 3. Most Relevant Authors

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Table 3. The Data of Author Impact

Author	Affiliation	h_index	g_index	m_index	TC	PY_start
Hwang G-J	National Taiwan University of Science and Technology (Taiwan)	9	13	0.6	673	2011
Chang C-Y	Taipei Medical University (Taiwan)	4	6	0.5	230	2018
Chesire F	University of Oslo (Norway)	4	4	1	38	2022
Kaseje M	Tropical Institute of Community Health and Development in Africa (Kenya)	4	4	1	38	2022
Lewin S	Norwegian Institute of Public Health (Norway)	4	4	1	38	2022
Li Y	Nanyang Medical College (China)	4	4	0.235	53	2009
Mugisha M	University of Oslo (Norway)	4	4	1	38	2022
Nsangi A	Makerere University (Uganda)	4	4	1	38	2022
Nyirazinyoye L	University of Rwanda (Rwanda)	4	4	1	38	2022
Oxman AD	Norwegian Institute of Public Health (Norway)	4	4	1	38	2022

4.3.2. Affiliations Leading Contributors

Affiliation plays a crucial role in scientific articles, as it is one of the requirements for submitting articles to journals and serves as an article's identity. The top 10 affiliations are presented in Figure 4. Of the top 10 affiliations, four are from Indonesia: Universitas Negeri Padang (33 publications), Universitas Negeri Yogyakarta (29 publications), Universitas Negeri Jakarta (22 publications), and Universitas Negeri Malang (22 publications). There are two other affiliations from Taiwan, namely the National Taiwan University of Science and Technology, with 28 publications, and the National Taiwan Normal University, with 16 publications. Other affiliations come from various countries, including Poland (the Medical University of Silesia, with 23 publications), Uganda (Makerere University, with 17 publications), Malaysia (Multimedia University, with 17 publications), and Hong Kong (The University of Hong Kong, with 16 publications). Based on the productivity of published articles, these affiliations certainly have in-depth scientific fields of study regarding the role of LTCTS, which are then used as articles published and indexed by Scopus.

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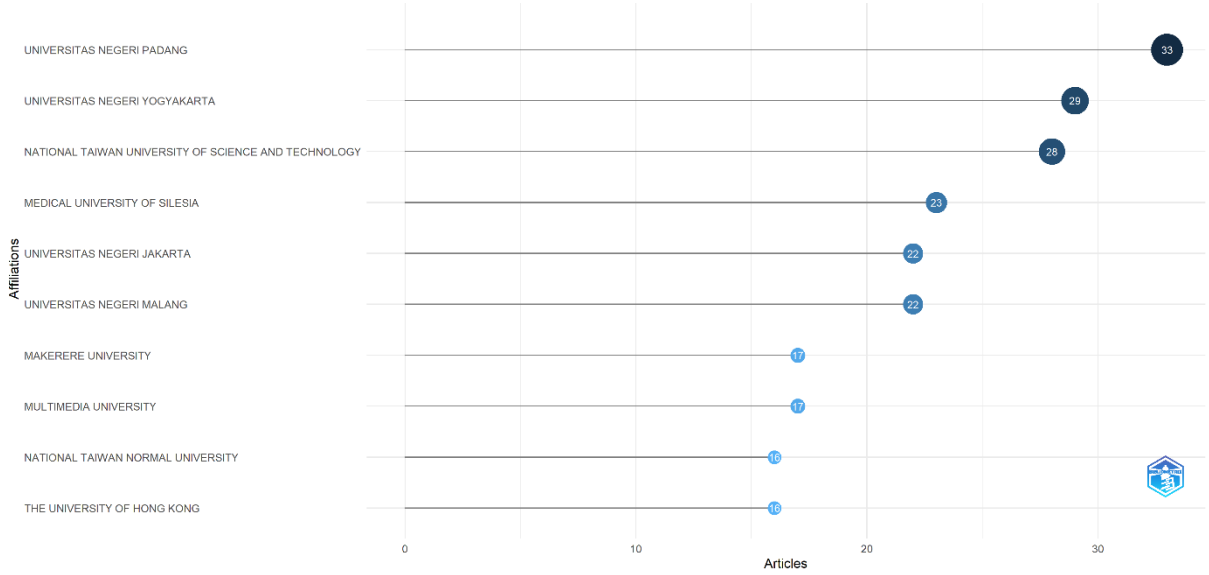

Figure 4. Most Relevant and Productive Affiliations

The data on the number of publications produced by affiliates over time (see Figure 5) provides information on how the research focus of each affiliate has developed over a certain period of time. Based on this data, of the 10 most productive affiliates, the National Taiwan University of Science and Technology and the National Taiwan Normal University were the first universities to publish articles in the research area of the role of LTCTS. National Taiwan University of Science and Technology first published 1 article in 2011, but the next publication was not made until 2018, and has continued to publish consistently until now. Meanwhile, National Taiwan Normal University (NTNU) began publishing 3 articles in 2014 and has been quite consistent until now. Although publications are not always produced every year, NTNU is one of the universities that pays attention to this research area and has published 1 article in 2025.

On the other hand, several universities have only recently started publishing in recent years, but with a significant focus, resulting in a considerable number of publications. Universitas Negeri Malang (UM) started publishing in 2020 with 9 articles and has continued to grow until now. On the other hand, other universities, such as Makerere University, Multimedia University, Universitas Negeri Jakarta, and Universitas Negeri Padang, have started to focus on this research area since 2022. In 2023, the University of Hong Kong and Universitas Negeri Yogyakarta only published research on the role of LTCTS. Even the Medical University of Silesia only started publishing in 2024. However, these universities are among the top 10 most productive universities due to the amount of attention given by these affiliates to this area of research.

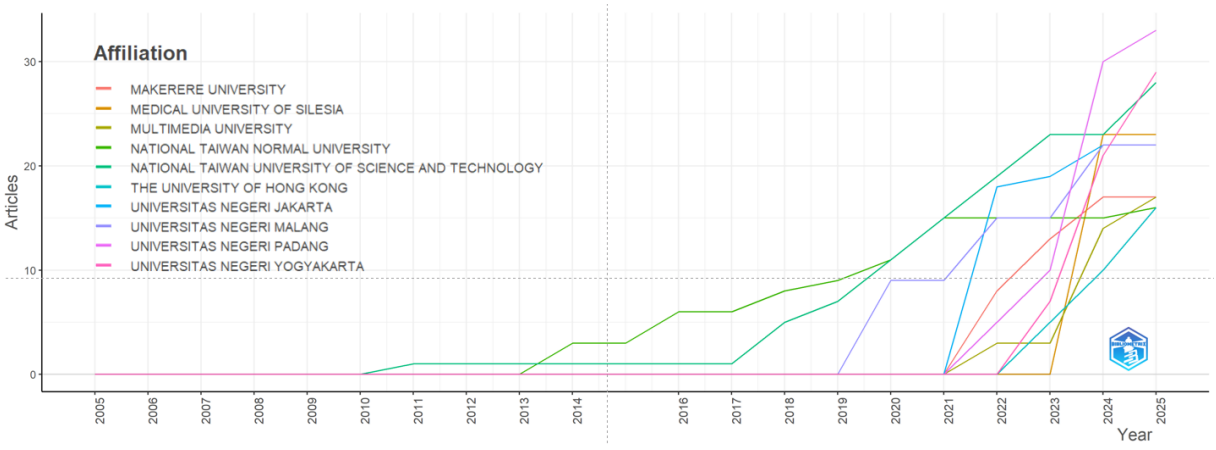

Figure 5. Affiliations' Production over Time

4.3.3. Country Leading Contributors

One of the important identities included in scientific articles is the author's country of origin. This certainly has an impact on a country's reputation based on the research outputs produced, including published articles. The 10 most frequent correspondents by country of origin are shown in Table 4. Based on these data, the USA is the country with the highest number of publications, with 110 (9.8%) articles, followed by China with 103 (9.2%) articles. Hong Kong is the 10th most productive country, publishing 18 (1.6%) articles.

In addition to the total number of publications, SCP (Single Country Publication) and MCP (Multiple Countries Publication) represent critical indicators, as they offer comprehensive insights into research collaboration patterns at both national and international levels. SCP highlights the extent of a country's contribution to domestic research, with collaboration patterns in single-country publications generally occurring more frequently among authors within the same institution or country. In contrast, MCP illustrates the scope of international collaboration networks, which can significantly impact the advancement of global scientific knowledge. Understanding these two collaboration patterns allows bibliometric analysis to discern global research trends and assess a country's research strengths within the broader international context.

Among the 10 most productive countries, Hong Kong is the country with the highest percentage of collaboration between countries (SCP = 11, MCP = 7, %MCP = 38.9). On the other hand, India is the country with the smallest percentage of collaboration between countries (SCP = 31, MCP = 3, %MCP = 8.8). In general, research conducted by authors from these 10 most productive countries has been quite good at conducting cross-country research collaboration.

Table 4. Data on the Number of Publications Produced by the 10 Most Productive Countries and Authorship Collaborations

Country	Articles	Articles %	SCP	MCP	MCP %
USA	110	9.8	94	16	14.5
China	103	9.2	87	16	15.5
Indonesia	88	7.9	80	8	9.1
United Kingdom	42	3.8	29	13	31
Australia	35	3.1	27	8	22.9
India	34	3	31	3	8.8
Malaysia	30	2.7	23	7	23.3
Spain	26	2.3	19	7	26.9
Canada	20	1.8	14	6	30
Hong Kong	18	1.6	11	7	38.9

Meanwhile, when viewed from the collaborating countries —the USA, the United Kingdom, and China —the three are included in the group of countries with high collaboration (Figure 6). Although the USA and China have a lower %MCP than the United Kingdom (see Table 4), authors from more than two countries dominate each article produced from international collaboration by the USA and China, the same as the United Kingdom, so that these three countries are included in the group of countries with high collaboration. In addition, some countries, such as South Africa, Chile, Mexico, Norway, and Kenya, appear more isolated, with fewer collaborative relationships, which could indicate they are just starting to build broader international research networks.

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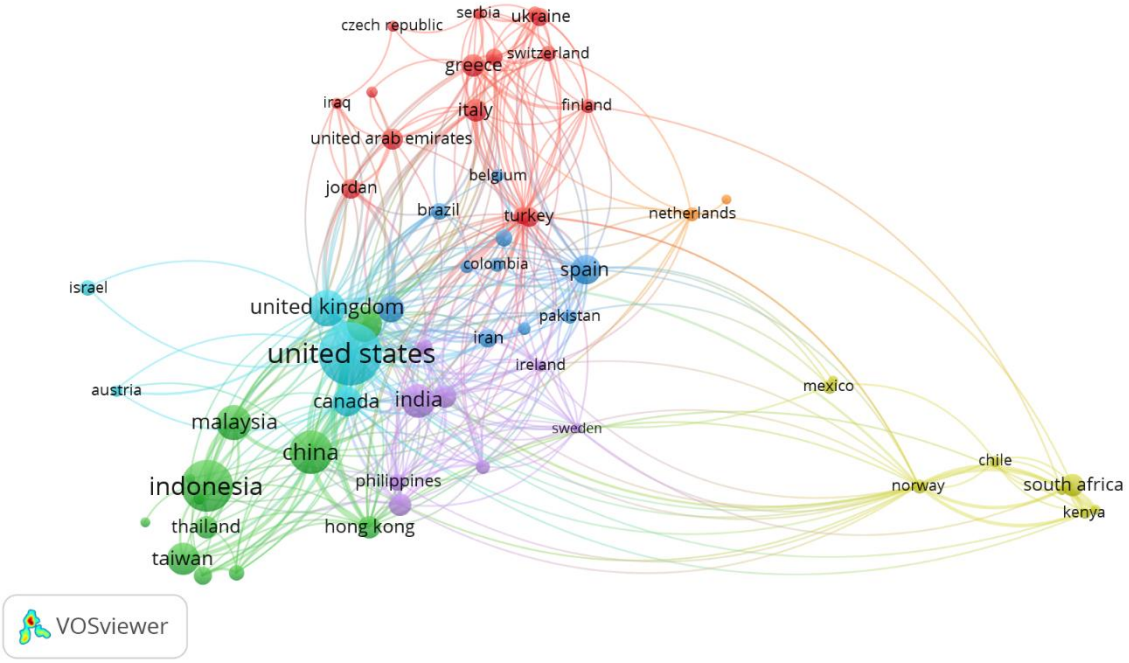

Figure 6. Visualization of International Collaboration Network

4.4. The Most Relevant Words about The Role of LTCTS (RQ4)

The most relevant words in the context of this paper are those that are most used or related to the research topic of the role of LTCTS. The most relevant words that are most often used in this topic in the time span of 2005-2025 are presented in Figure 7. “Critical Thinking” is the most frequently appearing keyword (203 appearances), which shows that critical thinking is the central topic in this research. This is followed by “Human” and “E-learning”, with 182 and 173 appearances, respectively, which shows that these two topics are closely related to the development of critical thinking skills, where technology-based learning (through e-learning) and human aspects are the main elements in the research. Furthermore, based on its relationship to learning and students, there were 155 occurrences of the keyword “students”, which shows the importance of students in the context of this research, especially how learning technology can influence or improve critical thinking skills among students. “Learning” and “Teaching” also occupy important positions, with 154 and 146 appearances, respectively, which shows that the topic of learning and teaching is a very relevant area in this research. Not only that, the keyword “Artificial Intelligence” (144 appearances) was also found, reflecting increased attention to the role of artificial intelligence in supporting the improvement of critical thinking skills through learning technology.

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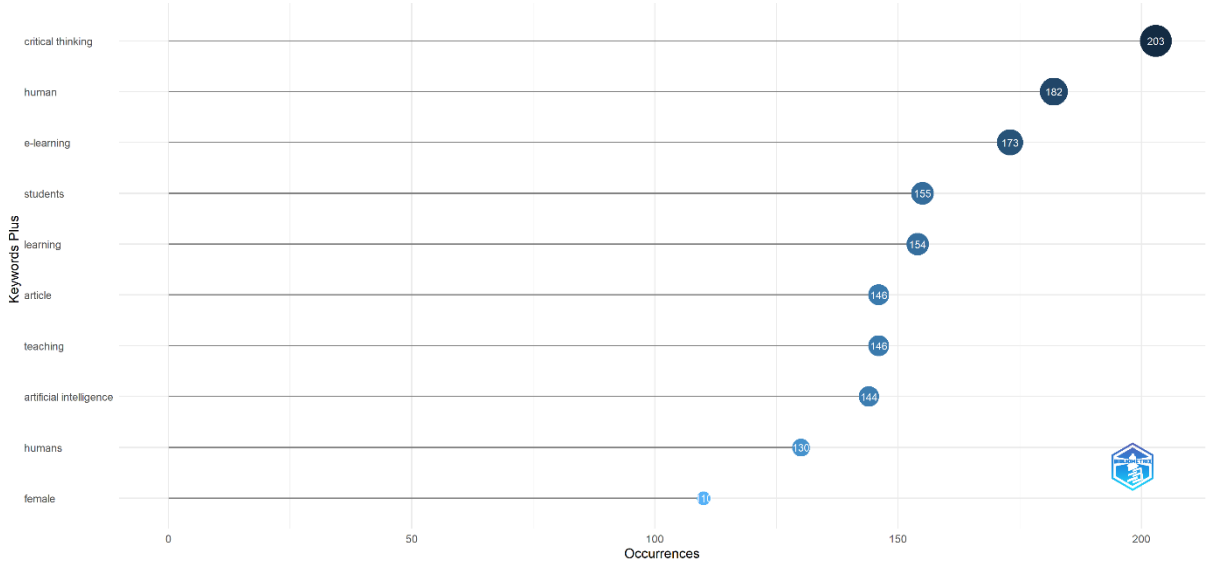

Figure 7. The Most Relevant Keyword about The Role of LTCTS

To see how the keyword has developed over the years, Figure 8 shows the cumulative frequency of words related to the topic of learning technology and critical thinking skills from 2005 to 2025. In general, based on the development of the cumulative frequency of relevant keywords, research related to the role of LTCTS is growing. The growing use of the keyword "critical thinking" shows that this 21st-century skill is increasingly gaining the attention of researchers globally, supported by the use of learning technologies such as "artificial intelligence" and "e-learning".

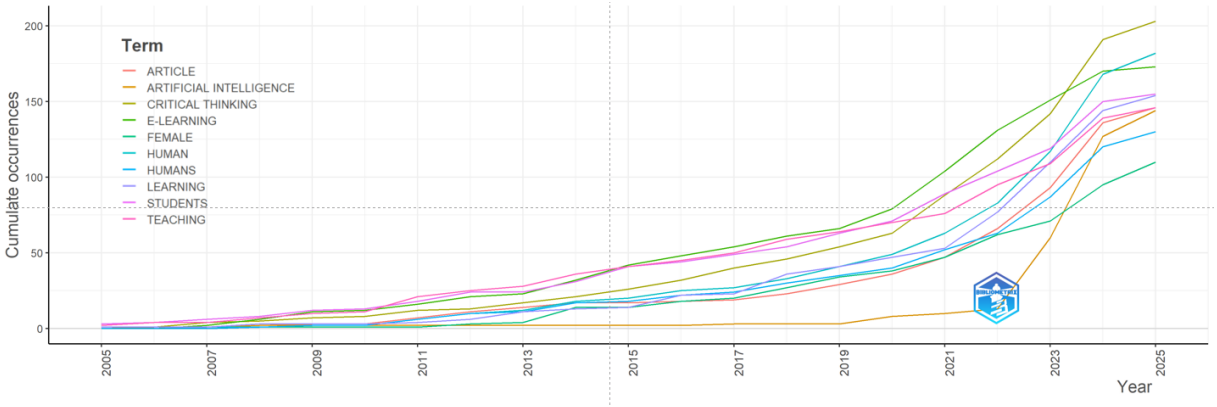

Figure 8. Words' Frequency over Time

4.5. The Direction of Future Research Focus (RQ5)

The network visualization created using VOSviewer in Figure 9 shows the relationship between various concepts in the field of education, especially those related to artificial intelligence, critical thinking skills, and learning. There are three large clusters that group keywords relevant to the research area. The first cluster (red) focuses more on "critical thinking skills", "e-learning", and "artificial intelligence in education". This shows that artificial intelligence is used to support the development of critical thinking skills through electronic learning platforms. Some other connected words include "generative artificial intelligence", "chatbots", "deep learning", and "higher education", which indicate the use of advanced technology in higher education. The second cluster (green) focuses more on "human", "curriculum", and "learning", which shows the relationship between human learning and effective curriculum development. Some connected keywords, such as "decision-making", "cognition", and "training" highlight the importance of decision-making and training in the learning process. Another important thing to note is the keyword "ethics", which is quite separate and has not been of much concern to many researchers so far. The third cluster (blue)

highlights “nursing education”, “clinical competence”, and “medical education”, which shows a focus on medical education and clinical competence. Several keywords such as “clinical practice”, “medical student”, and “clinical reasoning” indicate the importance of clinical education in shaping medical professionals by improving critical thinking skills through the use of learning technology.

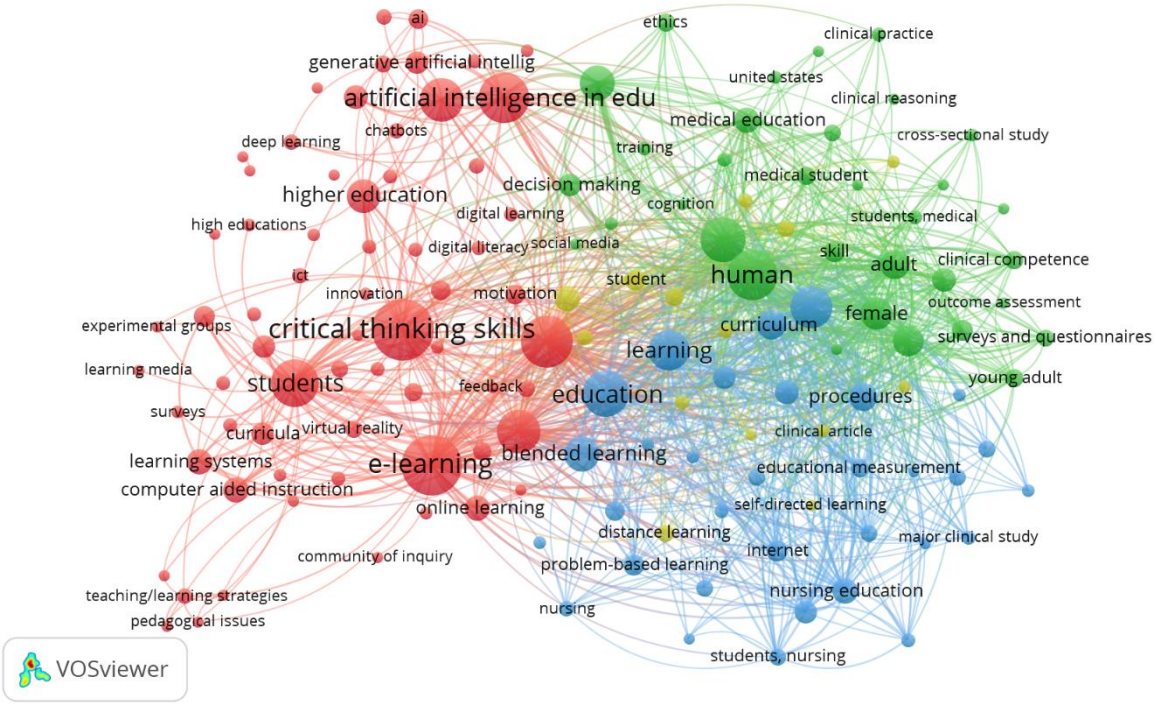

Figure 9. Visualization of The Network Connecting Keywords

The evolution of research topic focus from 2005 to 2025, as shown in Figure 10, reveals significant insights. During the period from 2005 to 2010, the primary research topics included "active learning," "pedagogical issues," "computer-aided instruction," "students," "online systems," and "decision making." This period primarily emphasized active learning and pedagogical issues, supported by online systems and computer-aided instruction. In the period 2011-2015, there was a transition in topics to “e-learning”, “teaching”, and “human”. This shift in research topics shows an increase in the adoption of technology in education. Furthermore, in the period 2016-2020, there are new topics such as “critical thinking”, “applications in subject areas”, and “social networking (online)”. Evolution focused on developing critical thinking skills and on applying technology across various fields of study. In this period, the use of online social networks began to be noticed. In the last period (2021-2025), the main focus of research is “human”, “critical thinking”, “learning systems”, and “students”. In this period, there has been consolidation in the development of learning systems and critical thinking skills, with particular attention to the role of humans and students in the educational process.

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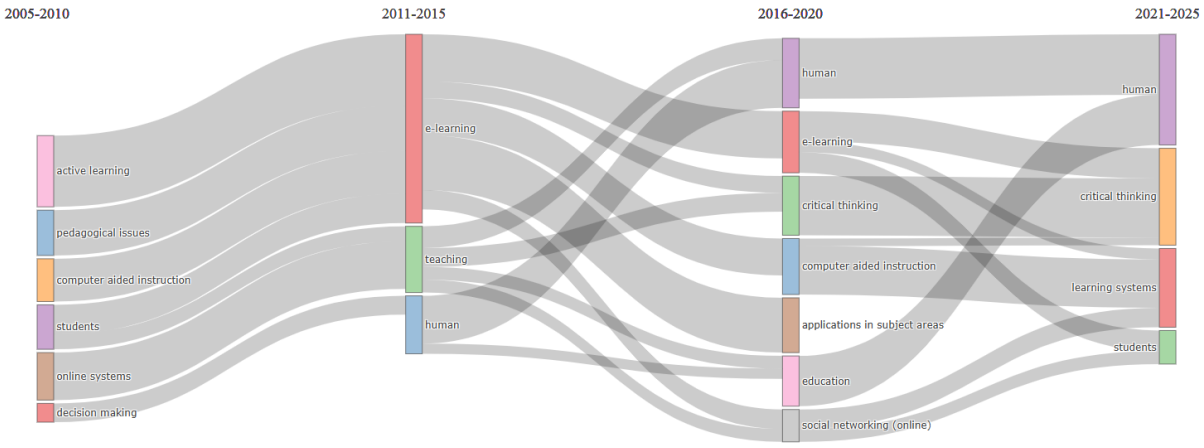

Figure 10. Thematic Evolution

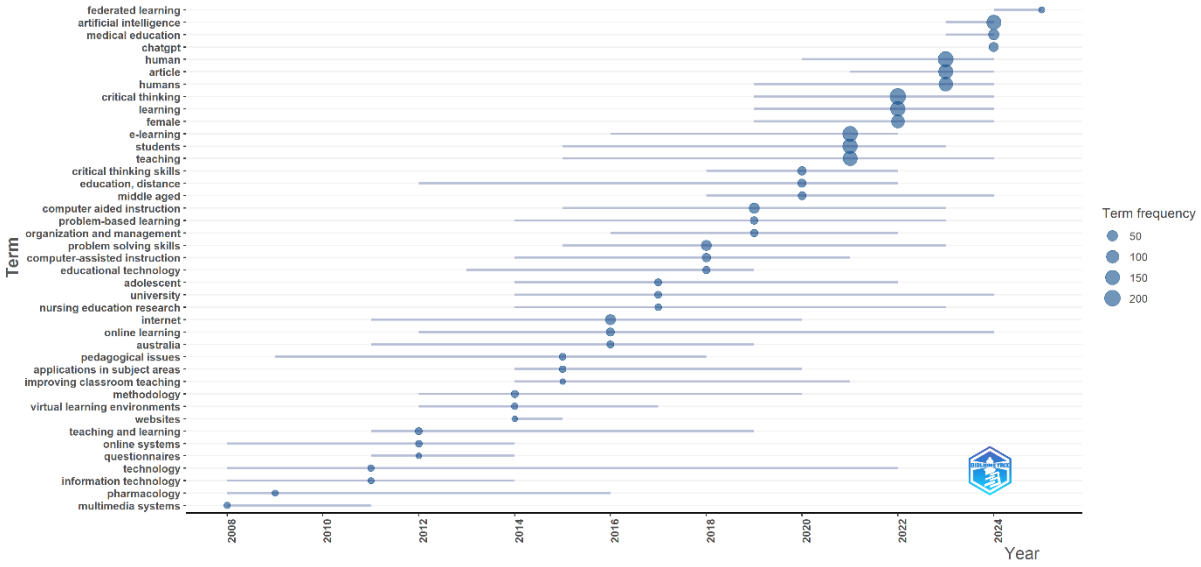

Figure 11. Trend Topics

In addition to the visualization of the network connecting keywords and thematic evolution, the development of research trends in an area can be seen based on trend topics, as shown in Figure 11. Many terms show an increase in frequency over time, indicating an increase in interest and research in these topics. Terms such as “artificial intelligence”, “critical thinking”, “e-learning”, and “medical education” are highly frequent and have become popular, especially in recent years. Based on the period of appearance of the term, terms such as “technology”, “information technology”, and “multimedia systems” began to appear in the initial period (around 2006-2010), indicating that the adoption of technology in education had begun to be widely practised, although this was not the initial period of utilization of technology in the education sector. Furthermore, in the period of further development (around 2011-2015), terms such as “online learning”, “virtual learning environments”, and “problem-based learning” began to gain attention. This shows a shift towards technology-based learning and innovative learning methods. Finally, the dominance of technology using artificial intelligence began in the period 2016-present, as terms such as “artificial intelligence”, “ChatGPT”, and “federated learning” show significant increases. In addition, the terms “medical education” and “nursing education research” also show an increase, signalling a strong focus on education in the health sector. An important finding in this section can also be seen from the term “federated learning”, which began to appear in 2024. This indicates one of the research directions that can be developed in the future.

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5. Discussion

This key information is very useful for researchers to understand the current research landscape and plan future research in learning technology and critical thinking. Based on the information presented in the key information (Table 1), it can be said that, in general, this field of research has received significant attention from many researchers from various countries based on the number of documents, the average number of citations per document, and the number of authors and countries involved. This data shows that learning technology and critical thinking skills have become central themes in contemporary education research. In addition, LTCTS topics are related to broader research areas, attracting attention across various disciplines based on the number of unique keywords (Cuéllar-Rojas et al., 2022; Koo, 2025). With this information, researchers can make choices and decisions about the research they will conduct in the future (Dao et al., 2023; Srivastava et al., 2024). From the main data, it can be concluded that this data is preliminary information in document analysis using Biblioshiny, which is very useful in providing an overview of research developments on specific topics that can be considered before researchers make decisions in choosing research topics and in which fields they will contribute to the scientific development process.

The trend in the development of publications has demonstrated a consistent year-over-year increase (Figure 2), which is consistent with the data presented in the main information (Table 1). This result is in line with the results of analyses conducted by several previous researchers, which show that research related to the use of technology in learning has increased over time (X. Chen et al., 2024; Goksu, 2021; Shen & Ho, 2020; Wang et al., 2024), as well as research on critical thinking skills (Castaño et al., 2023). This continuous growth may be attributed to the increasing integration of digital tools and platforms in educational settings, which are recognized for their potential to enhance cognitive abilities, including critical thinking. There has been no bibliometric analysis that comprehensively analyzes research developments on the topic of the role of LTCTS. Therefore, this finding contributes new insights into the trends, gaps, and future directions of LTCTS research, offering valuable guidance for both scholars and practitioners in the field. However, Suprapto et al. (2024) reports a significant increase in research on virtual reality-critical thinking skills in the past decade. This is certainly an indication of the growing use of technology in learning to improve critical thinking skills. Moreover, the convergence of learning technologies with cognitive development strategies could open new avenues for research, underscoring the need for deeper exploration of how these technologies can be optimized for better learning outcomes.

An additional significant point to highlight is that research topics pertaining to the use of technology in learning, particularly those focused on enhancing critical thinking skills, have continued to evolve despite the challenges posed by the COVID-19 era. Some research topics have actually shown a decrease in the number of publications produced during the COVID-19 pandemic, such as on the topics of conceptual change (Amiruddin et al., 2025; Amiruddin, Samsudin, et al., 2024), Technological Pedagogical Content Knowledge (TPACK) (Amiruddin, Agustin, et al., 2024), and Project-Based Learning in Science Education (Kadirhanoğulları & Köse, 2024). In the context of learning, the role of technology will continue to be needed even if circumstances change from normal, as during the COVID-19 era, which forced learning to be done virtually. The proper use of technology will always help the learning process and make learning more adaptable to the challenges that arise.

Not only has the number of publications increased over the past two decades, but the average number of article citations is also quite high (Table 2). Based on this data, the research topic aligns with current studies, supporting Trajtenberg's (1990) assertion that highly cited articles reflect contemporary research trends. This shows that the role of learning technology in developing critical thinking skills has not only gained attention but also had a significant impact on the research community, thereby gaining widespread recognition and influence in this field. This recognition and

influence are indicated by the large number of citations, meaning that the findings from these articles are used as references in a wide range of research (Aksnes et al., 2019; C. Chen & Song, 2019; Singh & Thurman, 2019). This, of course, provides stronger support for the claim that the topic of this research is very relevant at this time. The results of Sjögårde & Didegah's (2022) research across eight disciplines show that publications in rapidly growing topics receive more citations than those in slow-growing or declining topics, as indicated by regression model analysis. Sjögårde & Didegah's findings further confirm that research in the LTCTS area is not only increasing in volume but also in its scholarly impact and relevance. However, in addition to being relevant to current topics, the articles that we analyze in this publication must be of good quality. We believe that even if an article is highly relevant to a current topic but of low quality, other researchers will not use it as a reference. Based on the results of the analysis by Mammola et al. (2021) on ecological literature, widely cited articles tend to be of good quality, have a longer list of references, cite more recent and impactful references, and include more independent citations. This supports the idea that the credibility and authority of an article play a crucial role in its citation frequency, making high-quality studies not only influential but also foundational for further research.

An additional key finding to highlight is the global scope of this research, which was conducted across multiple countries. This means that a research topic needs to be conducted if it is a global issue (although local issues in a narrow scope are also important), and it would be better if it involved many countries. In general, the 10 most relevant authors (Figure 3) who have the most publications on LTCTS research also have the highest impact (Table 3) based on h-index, g-index, m-index, and total citations, although there are several authors who are among the 10 most impactful authors but are not among the 10 most relevant authors. This finding shows that even though a particular author produces a lot of articles, they may not have a big impact if the articles produced are not relevant to the developing topic. This is in line with the opinions of Baas et al. (2020), Khatter et al. (2021), and Paul et al. (2021), who state that quantity does not guarantee the quality of an article in a journal, an article in proceedings, or a book. Therefore, the indexer categorizes quartiles to map journals based on the impact generated in order to see which articles in which journals have a high impact in a research area (Oldac, 2022; Petr et al., 2021; Singson et al., 2025). Not only that, in the LTCTS research area, the most productive affiliations and the most productive countries show quite different results. The most productive affiliations are dominated by universities from Indonesia (Figure 4 and Figure 5), and there are no universities from the USA and China. On the other hand, the USA and China are the two most productive countries based on the number of articles produced, with Indonesia being the third most productive country. The results of this study show that, although the number of articles produced by the USA and China is large, the work is produced by many affiliates, not dominated by a few specific affiliates. On the other hand, Indonesia has thousands of universities, but there is not much focus on the LTCTS research area, so campuses with an LTCTS research focus produce many articles. This is a common occurrence and is found in several other research areas (e.g., Ngu et al., 2025; Tajuddin et al., 2025).

If the collaboration between countries is considered, LTCTS is a research area that involves many countries with quite strong collaboration. All countries that have produced articles in this research area have collaborated, albeit with different %MCP (Table 4). This demonstrates the global relevance of the LTCTS field and underscores the importance of cross-border research networks in addressing complex educational and technological challenges. Collaboration between countries is important to see how a country handles an issue and the reasons behind the underlying variations (Mansoor, 2025). Such collaboration provides an opportunity for researchers from different cultural and academic backgrounds to pool their expertise, which can lead to more innovative solutions and a broader understanding of how learning technology can enhance critical thinking skills in diverse educational contexts. On the other hand, collaboration between countries is also an important aspect

that needs to be analysed in bibliometric analysis (Kitajima & Okamura, 2025; Luthfiyah, 2025; Ma & Ismail, 2025). With collaboration between countries, authors will exchange insights and provide different perspectives to solve the problems they are facing (Claessens et al., 2024; Cundill et al., 2019; Freshwater et al., 2006). This exchange of ideas often results in more robust research findings that can be applied in various educational settings, which plays an important role in driving both local and global progress in this field.

Learning technology can be interpreted as a general term that includes various information communication technologies used to support learning, teaching, and assessment (Kirkwood & Price, 2014; Q. Liu et al., 2020). This provides an overview of the process by which individuals integrate learning technology into their educational practices (Straub, 2009). Learning technology is widely used, ranging from traditional to modern learning technology, and continues to evolve to this day. Currently, modern learning technology is more promising in supporting quality learning, although traditional learning technology is still needed in certain conditions. In the learning process, the integration of innovative tools and platforms has shown a positive impact on the efficiency, involvement, and knowledge acquisition of learners in various fields (Antonov et al., 2024). Today, many learning technologies are integrated into learning, which has a positive impact on students' skills, including critical thinking skills. The latest learning trends integrate learning technologies to improve critical thinking skills, such as Augmented Reality (Efendi et al., 2025; Sukmawati et al., 2024), Virtual Reality (Pears et al., 2025), animation (Pratiwi et al., 2022; Suwardika et al., 2024), simulations (Alharbi et al., 2024; Baharom et al., 2025; Oanh et al., 2024), and virtual practicums (Istianah et al., 2025). The use of this technology is suitable for building and training students' critical thinking skills because it trains them to be able to analyze and synthesize information, assess the accuracy of data sources, and solve problems.

The evolution of research themes shows that current LTCTS issues are moving towards learning systems (Figure 10), which focus on learning that creates learning environments that utilize technological advances, as in several previous studies. For example, Wu et al. (2025) analyzed the factors influencing students' aspirations that impact the use of mobile learning systems. Additionally, Li et al. (2025) designed and evaluated an interactive learning system based on human-computer interaction technology in early childhood education. With the use of technology, learning methods have undergone many changes. One of the most striking changes is that learning does not always have to be done face-to-face (Mishra et al., 2021). Our analysis shows that learning technology in improving critical thinking skills is also closely related to distance learning, online learning, and blended learning, which is in line with the findings of Yates et al. (2021), Bilal et al. (2022), and Mutalib et al. (2022). However, face-to-face learning cannot be completely replaced by distance learning. In addition to the challenges inherent in implementing distance learning, in some cases, face-to-face learning has proven to be more effective than distance learning (Foo et al., 2021).

Undoubtedly, the research trend related to LTCTS continues to grow, with federated learning emerging as a prominent topic in this field (Figure 11). As stated by Bharati et al. (2022), federated learning research is developing rapidly. Federated learning is a distributed machine learning method in which models are trained collaboratively by multiple devices or servers without transferring raw data between them. In federated learning, data remains on each device (e.g., smartphones, computers, or local servers), and only model updates are sent to a central server. This approach helps maintain data privacy and security, as personal data never leaves the device (Hernandez-Cruz et al., 2024). Not only federated learning, but recent research trends also show that LTCTS is closely related to artificial intelligence, including ChatGPT.

These results also indicate that the integration of technology in learning today is not merely limited to the use of online learning systems, such as websites or MOOCs, but has evolved toward the utilization of artificial intelligence and machine learning. The use of sophisticated artificial

intelligence plays an important role in improving learning efficiency, so it is widely used by instructors, and empirical evidence of its effectiveness has become a focus of many researchers (Park & Kwon, 2024). This certainly presents new challenges for researchers, particularly in the fields of education and technology development that are beneficial for learning. According to Lin & Yu (2024), chatbots are a rapidly growing issue, with technological advances, students' perceptions of chatbots, and the effectiveness of chatbots in different educational contexts becoming the most popular research topics. Hwang & Tu (2021) also found that AI is developing rapidly in mathematics education, but there are still many things that have not been researched, such as empirical evidence on the effectiveness of using AI in mathematics learning activities from various perspectives, such as cognitive load, collaboration and communication competencies, and learning anxiety, which are rarely considered research focuses. This has also not been done much in learning in various disciplines. Accordingly, learning related to AI will become a highly promising topic for future development. With the rapid development of artificial intelligence (AI) in education, ethics is becoming increasingly important, and research on ethics in AI will continue to evolve as new cases arise (Taqwa, 2025). This research will be necessary to achieve fair ethical use. Core principles such as fairness, transparency, accountability, and privacy in the development of ethical artificial intelligence (AI) will continue to be needed (Shin, 2025).

Although we have successfully provided an overview of the developments in research related to LTCTS and offered suggestions for future research directions, we recognize that this study has several limitations. The data we analyzed were the results of searches based on the queries or keywords we used. We have tried to carefully consider that the queries we used could comprehensively capture the data, but there is still a chance that relevant documents were not captured, especially those related to educational technology, due to its broad scope. Although Scopus is a large and comprehensive database, we acknowledge that data sources other than Scopus also have good quality and were not analyzed. Nevertheless, we remain optimistic that our analysis provides a comprehensive overview to assist researchers, especially in guiding their future work.

6. Conclusion

This bibliometric analysis provides valuable insights into the evolving role of learning technology in enhancing critical thinking skills (LTCTS) from 2005 to 2025. The research has shown a significant increase in the number of publications and citations, reflecting growing academic interest in this area. The analysis also reveals a strong global collaboration, with diverse contributions from authors, affiliations, and countries, particularly in the context of technological advancements such as artificial intelligence and e-learning platforms. The trends highlight a shift towards integrating AI-driven tools and learning systems to foster critical thinking, with key areas for future research including federated learning and the ethical implications of AI in education. Despite some limitations in data sources, this study offers a comprehensive understanding of the current state of LTCTS research and outlines promising directions for future exploration, contributing to the academic community’s ongoing efforts to leverage technology in improving education.

7. Suggestion

Building on the findings and discussions of this bibliometric analysis, several suggestions can guide future research, policy, and practical implementation in the field of Learning Technology for Critical Thinking Skills (LTCTS). From a methodological perspective, future studies should broaden their scope by sourcing documents from multiple academic databases while ensuring the inclusion of high-quality sources. From an empirical standpoint, further research should examine the effectiveness of emerging technologies such as federated learning, generative artificial intelligence (e.g., ChatGPT), and immersive technologies (AR/VR/MR) in fostering critical thinking skills across diverse educational contexts. With the increasing integration of AI in education, ethical

considerations—such as fairness, transparency, accountability, and privacy—must be prioritized, accompanied by strategies to mitigate bias and ensure responsible AI use. Moreover, longitudinal and experimental research designs are needed to assess the long-term impact of learning technologies on the development and retention of critical thinking skills. This study also underscores the importance of expanding and strengthening international collaboration to enrich perspectives, develop context-sensitive solutions, and ensure the transferability of findings across cultures and educational systems. On a practical level, research should bridge theory and practice by providing frameworks, training, and case-based guidelines that educators can directly apply in classroom settings. Finally, policy support and institutional strategies are essential to promote the adoption of evidence-based LTCTS interventions, including the provision of funding, infrastructure enhancement, and teacher training programs to ensure equitable access and sustainable implementation.

Declarations

Author Contributions. Taqwa: Conceptualization, design, data analysis, writing, project administration. Sinaga: Editing/reviewing, visualization, supervision, and final approval. Suhendi: Editing/reviewing, critical revision of manuscript, and final approval. Feranie: Editing/reviewing, critical revision of manuscript, supervision, and final approval. Yusof: Conceptualization, design, data analysis. All authors have read and approved the published version of the article.

Conflicts of Interest. On behalf of all authors, the corresponding author declares that there are no conflicts of interest.

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Ethical Approval. The research has been approved by the ethics committee of Universitas Negeri Malang with No. Reff 29.7.25/UN32.14/PB/2025.

Data Availability Statement. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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