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BRAIN AND CRITICAL THINKING IN EDUCATION: A BIBLIOMETRIC REVIEW AND WORDCLOUD ANALYSIS

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Abstract

This article uses data from the Scopus database for bibliometric review and wordcloud analysis visualization of publications related to Brain and Critical Thinking in Education (BCTE). The study highlights the importance of the brain in the learning process and critical thinking, as well as identifying research trends, key topics, and geographic distribution of authors over the decade 2013-2023. With a focus on English-language publications, the study reveals that "critical thinking" is the most frequently cited topic, with the United States as the most significant contributor. This analysis also suggests the need for further research that integrates brain-based learning with critical thinking to improve students' critical thinking and 21st-century skills in education. Understanding how the brain works will enable educators to design a comprehensive learning plan, including teaching materials, implementation, media, models, strategies, approaches, and appropriate methods, to achieve learning goals.

Keywords: education; critical thinking; brain; bibliometric; wordcloud analysis

Abstrak

Artikel ini menggunakan data dari database Scopus untuk review bibliometrik dan visualisasi analisis wordcloud dari publikasi terkait Brain and Critical Thinking in Education (BCTE). Studi tersebut menyoroti pentingnya otak dalam proses pembelajaran dan berpikir kritis, serta mengidentifikasi tren penelitian, topik utama, dan distribusi geografis penulis selama dekade 2013-2023. Dengan fokus pada publikasi berbahasa Inggris, penelitian ini mengungkapkan bahwa "berpikir kritis" adalah topik yang paling sering dikutip, dengan Amerika Serikat sebagai kontributor paling signifikan. Analisis ini juga menyarankan perlunya penelitian lebih lanjut yang mengintegrasikan pembelajaran berbasis otak dengan berpikir kritis untuk meningkatkan pemikiran kritis siswa dan keterampilan abad 21 dalam bidang pendidikan. Memahami cara kerja otak akan memungkinkan pendidik merancang rencana pembelajaran yang komprehensif, meliputi bahan ajar, pelaksanaan, media, model, strategi, pendekatan, dan metode yang tepat, untuk mencapai tujuan pembelajaran.

Kata kunci: *pendidikan; berpikir kritis; otak; bibliometrik; analisis wordcloud*

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Introduction

The brain is the most complex machine of billions of nerve cells that are consciously interconnected to produce thoughts and experiences (Dubin, 2013). The brain is a place to think and imagine cognitive activities that make it possible to consider and interpret the situation (Collin et al., 2020). Brain-based learning is a method in harmony with the brain's working mechanisms, which instinctively stimulates and deepens curiosity through an intuitive learning process (Jensen & McConchie, 2020). Brain-based learning emphasizes that the dynamic interaction between emotions and intelligence is critical to improving learning (Connell, 2016). A shift in learning with a brain-based learning approach has occurred to improve educational practices (Jensen, 2008) where five dimensions of brain function, namely cognitive, emotional, kinesthetic, social, and reflective, are integrated into the design and implementation of learning experiences (Given, 2002).

Brain-based learning is a method that aligns with the working mechanisms of the brain, which instinctively stimulates and deepens curiosity through intuitive learning processes (Jensen & McConchie, 2020). Brain-based learning is an approach that views learning processes and outcomes through the lens of brain function, with strategies involving steps and practices designed according to theories related to brain work (Mohammed & Daif-Allah, 2024). According to the theory of how the brain works, brain activity can increase cognitive activity (critical thinking) with a brain-based learning approach, stimulating curiosity with practice and experience.

Teachers can design a classroom environment that supports effective learning by creating a positive, relevant, and engaging environment for students and using triggers that can trigger good brain responses. Research on brain-based learning is increasingly prominent and continues to develop in the world of education at various levels of education, which aims to improve learning achievement in complex concepts (Mekwan & Poonputta, 2023), metacognitive thinking skills (Sahin et al., 2023), critical thinking (Azzahra & Dwiputra, 2024; Juniatri et al., 2022; Rahmawati et al., 2024). Encouraging new research on brain-based learning has been proven to provide benefits, especially in improving the quality of education (Azzahra & Dwiputra, 2024).

Thinking is considered a mental process involving existing knowledge (Wibowo et al., 2024). Critical thinking, an essential skill in the 21st century, has become a significant focus for educators and researchers (Dilekçi & Karatay, 2023; Karaca-Atik et al., 2023; Park et al., 2023; Thornhill-Miller et al., 2023). Critical thinking requires cognitive skills and intellectual attitudes essential for identifying, analyzing, and assessing arguments and claims, uncovering and addressing biases, drafting and presenting solid arguments, making logical and informed decisions (Bassham et al., 2019), and intimately linked with scientific argumentation skills (Suliyanah et al., 2024). Educating about critical thinking is the focus of researchers to form future generations capable of disseminating and evaluating information (Sutoyo et al., 2023). Teachers can encourage higher-order thinking skills by adopting innovative educational media (Syahfitri & Muntahanah, 2024). Critical thinking is one of the skills students need in dealing with real-world problems because it produces new, meaningful knowledge and understanding when learning, no longer memorizing concepts and formulas (ŽivkoviL, 2016). Therefore, teachers as educators need critical thinking skills because this is comparable to improving 21st-century skills (Kuloğlu & Karabekmez, 2022).

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Many articles have discussed the brain and critical thinking in education, but other researchers have not yet carried out those that specifically discuss bibliometrics in schools. Bibliometric analysis provides budding researchers with valuable insights into the research and uncovering areas that need further investigation. Bibliometric surveys, especially in the context of the brain and critical thinking in education (BCTE), help to understand the dynamics of this research. The objectives of this analysis include classifying BCTE publications, exploring publication languages, assessing annual publishing trends, determining geographic contributions, analyzing trends by source, identifying lead authors, and evaluating BCTE publication topics and categories.

Method

There are two main methods to access scientific works such as articles, book chapters, and research documents: open access and paid access. In paid access, readers must pay a fee to open the document. In contrast, open access allows readers to access the document at no cost (Ma & Lee, 2017; Miguel et al., 2016; Zhang et al., 2019), usually by registering on the publisher's website. In addition, articles can be accessed through the institution's library portal or by accessing research databases such as Scopus, Web of Science, Science Direct, Research Gate, and Google Scholar. As one of the most frequently used databases Scopus (Herrera-Franco et al., 2020; Malanski et al., 2021; Mishra et al., 2021; Sugiarti et al., 2024; Yas et al., 2020) offers extensive research documents from various disciplines, including science, medicine, management, arts, engineering, agriculture, and education. Each article submitted to the journal through Scopus undertakes a peer review process (Feliciani et al., 2019; Hodonu-Wusu, 2018), where experts in the field evaluate and provide feedback on the feasibility of publication of the manuscript (Ali & Watson, 2016). Because it covers a wide range of international research articles, Scopus is considered a good starting point for research. The journals providing the publication results have ensured that the research articles have been evaluated strictly and that they present data and information with quality and value. This is why the selection of articles comes from Scopus data.

Bibliometric analysis is a tested and effective technique for examining and processing large-scale scientific data (Ardito et al., 2019; Lu & Zhang, 2022; Sriwannawit & Sandström, 2015). This technique facilitates tracing evolutionary trends in a field while revealing its general picture. This study outlines the bibliometric analysis of BCTE publications in Part 2, highlighting the initial dataset from 2013 – 2023. The analysis of BCTE publication data in the last ten years was conducted to provide information on the latest progress in BCTE publications. Part 3 demonstrates the data extracted from Scopus, accessed on April 5, 2024, introducing three analytical methods: statistical analysis of general information, particular information, and networks. Part 4 visualizes BCTE publications using word clouds with different areas. The conclusion of this study is presented in Part 5, and this paper closes with a bibliography.

Keyword and Language Assignment

It is crucial to set keywords to generate searches relevant to BCTE publications in the Scopus database, namely "brain-based learning," "critical thinking," and "education," for the period 2013 – 2023. Furthermore, these keywords determine English as the primary language used in BCTE publications, as detailed in Tables 1 and 2.

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Table 1. BCTE Keyword Assignment

Keyword Determination
TITLE-ABS-KEY (brain AND based AND learning AND critical AND thinking AND education) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "English"))

Table 2. Language designation for BCTE publications

Language	Result
English	29
Other	1

Document analysis using PRISMA 2020 resulted in 51,489 documents with the keyword "brain-based learning," shrank to 99 after adding "critical thinking." The adjustment for the 2013 – 2023 period reduces the number to 72 documents. The focus on English resulted in 71 documents, and the restriction on the "education" field provided 29 documents ready for analysis. The details are presented in Figure 1.

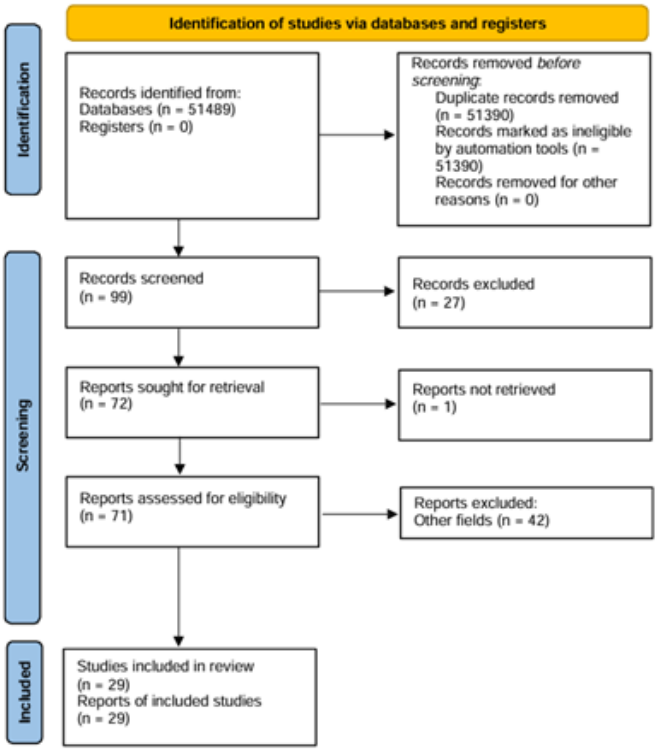

Figure 1. BCTE Keyword Flow Chart and Publications Language

Basic Data Acquisition

BCTE publication data from the Scopus database includes articles, reviews, conference papers, etc. Based on keywords, 29 documents were found, with the most articles at 41.8%, followed by conference papers at 31%. Further specifics are in Table 3 and Figure 2.

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Table 3. BCTE Publications Category Classification

Publication Category	Number of Publications
article	12
conference paper	9
reviews	3
book chapter	2
book	1
conference review	1
note	1

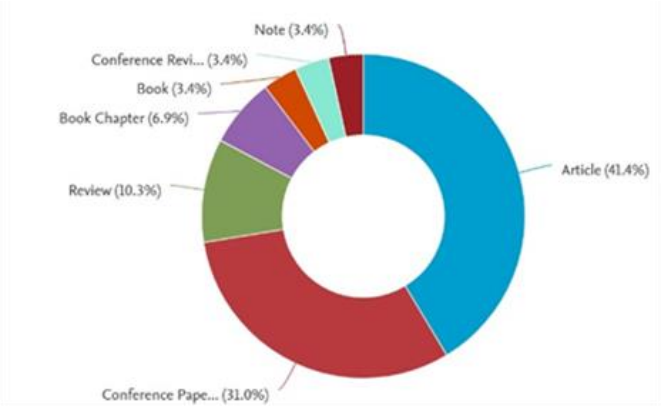

Figure 2. Percentage of BCTE publications category

Highlights and Interpretation of Basic Data

BCTE publications from 2013 – 2023 show increased researchers' interest in 'the brain' and 'critical thinking in education.' The diversity in the selection of materials, locations, and authors marks the uniqueness of this field. The publication peak occurred in 2021, while in 2014 and 2017, there were no recorded publications in Scopus, as shown in Figure 3.

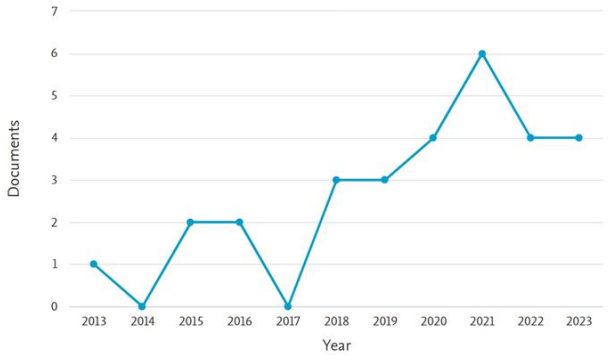

Figure 3. BCTE publications during the decade 2013 – 2023

The analysis of BCTE publications is limited to data from Scopus between 2012 and 2023 and does not contain additional databases such as Web of Science or Google Scholar. This can cause research bias, especially in bibliometric analysis, since English dominates the language used in BCTE publications. As a result, this BCTE research still needs to be evaluated using various databases and languages to be more precise and extensive.

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Results and Discussion

Bibliometric Review

The bibliometry analysis of BCTE publications was carried out through: 1) Statistical analysis of primary information that outlines the number of sources, documents, authors, author keywords, and author affiliation origins; 2) Statistical analysis of particular information detailing topic trends, subject areas, and the geographical distribution of authors. 3) Network analysis that visualizes publications' intertopic, density, and thematic relationships.

Statistical analysis of primary information

Figure 4 displays the main information of BCTE publications, with 26 sources, such as journals, books, conferences, and others, found between 2013 and 2023. According to the previous table 3, the number of BCTE publication documents is 29. Journal of Physics: Conference Series is the top source, followed by Education Sciences. For the IEEE Latin American Electron Devices Conference source, the third to tenth ranks (Information Science Letters) have the same number of documents, as seen in Figure 5.

Figure 4. Main information on BCTE publications

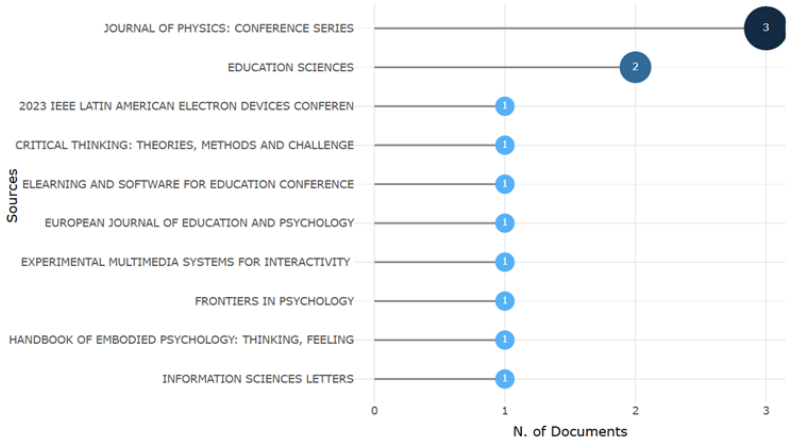

Figure 5. Ten sources of BCTE publications

From the BCTE publication search results, 29 documents were identified by 83 authors, 4 of whom were single authors and 133 different keywords. Information about the ten authors with the most contributions, each of whom published one document, is presented in Figure 6. There are 25 author affiliations, with Universitas PGRI Madiun Indonesia ranked in the top three, as explained in Figure 7.

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From 2019 to 2023, Universitas PGRI Madium published its research results on BCTE in four articles yearly.

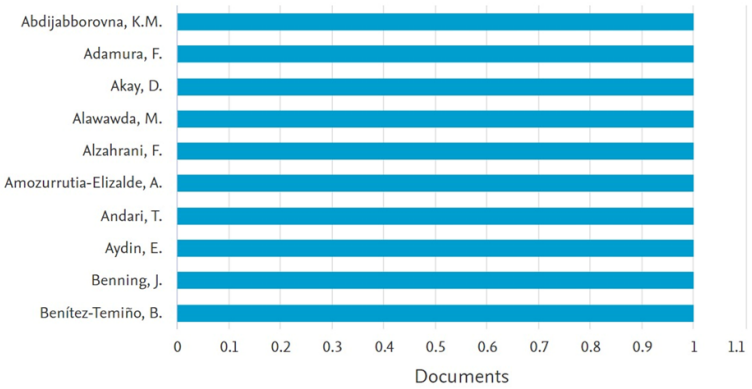

Figure 6. Top ten authors of BCTE publications

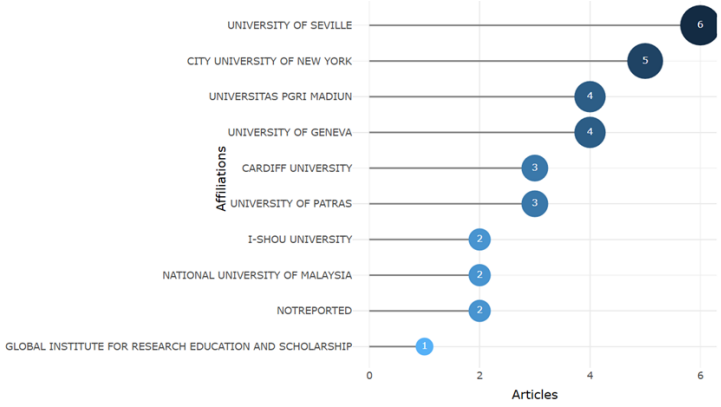

Figure 7. Top ten author affiliate origins BCTE publications

Statistical analysis of particular information

During 2013 – 2023, BCTE research highlighted "critical thinking" as the main keyword, with a significant increase in publications in 2022 and 2023. "Brain" emerged as a new topic in 2015 and continues to grow into a substantial trend. The issues of "human," "humans," "teaching," and "curriculum" also consistently appeared. More details are available in Table 4.

Table 4. Frequency of BCTE publications topics from time to time

Year	Critical thinking	Brain	Education	Students	Human	Humans	Teaching	Curriculum	e-Learning	Engineering education
2013	1		0	0	1	1	1	2	0	0
2014	1		0	0	1	1	1	2	0	0
2015	2		1	1	0	2	1	2	3	0	0
2016	2		2	2	1	2	1	3	3	0	1
2017	2		2	2	1	2	1	3	3	0	1
2018	3		4	3	1	3	2	3	3	0	1
2019	5		5	5	2	3	2	3	3	1	1
2020	6		6	5	2	3	2	4	3	2	1
2021	7		6	5	3	4	3	4	3	2	1
2022	9		7	5	5	4	3	4	3	3	2
2023	9		7	6	6	5	4	4	3	3	3

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Figure 8, a circle diagram, shows that social science dominated BCTE publications with 28.6%, computer science with 20.4%, and psychology with 12.2%. The arts, humanistic, and material science fields had lower contributions, at 2.0%. Ten subject areas of BCTE publications were presented.

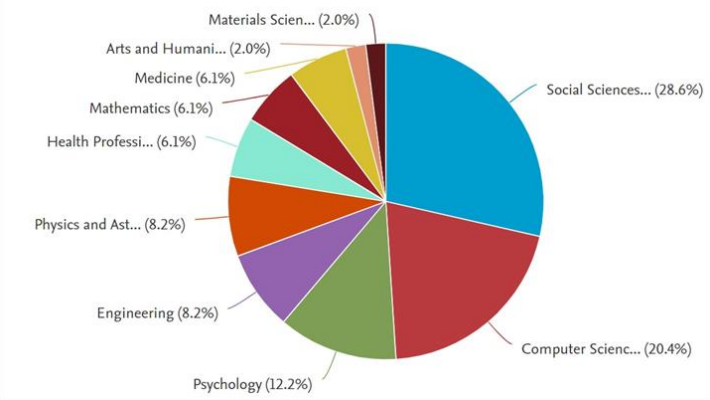

Figure 8. Subject areas of BCTE publications

Figure 9 shows the global distribution of BCTE research authors through an interactive map generated by R software. Countries in dark blue signify the highest number of BCTE publications, with the United States leading the way, followed by Malaysia and Spain. Indonesia, Colombia, the Netherlands, and Switzerland have four publications yearly in the top ten. Further details are presented in Table 5.

Table 5. Top ten countries of BCTE publications production

Country	Frequency
USA	15
Malaysia	10
Spain	9
Greece	7
Mexico	6
Colombia	4
Indonesian	4
Netherlands	4
Switzerland	4
UK	3

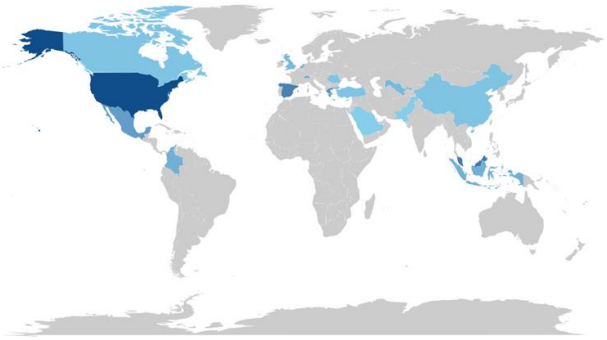

Figure 9. Geographical distribution of authors

Visualization of the geographical distribution of authors based on country, as shown in Figure 9 below, can be explained through the color distribution. There are two color groups in the visualization, namely blue and gray. The distribution of countries contributing to BCTE publications is marked with a blue distribution. The dark blue color visualizes the geographical distribution of authors with the most

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contributing countries. The more the blue color fades, the less the government contributes to BCTE publications. The gray distribution is a country that has never contributed to BCTE publications.

Network analysis

Network analysis is a visualization method that describes the interaction between various networks with various computational attributes (Farasat et al., 2015). The sensitivity of this analysis to the selected estimation variable shows the importance of choosing the correct variable (Hevey, 2018). In artificial networks, this method is used to develop graph mining models that contain a wide range, such as link prediction and recommendations, community and anomaly detection, and data classification and segmentation (Tabassum et al., 2018). Data and visual representations for various categories are collected to gain greater insight into the research field (Samala et al., 2024). An analysis of BCTE's publication network through R software shows that "critical thinking" is the main topic, often associated with "brain," "education," and others. The size of the symbol shows the frequency of the topic, and the network lines depict the relationships between the issues, as shown in Figure 10.

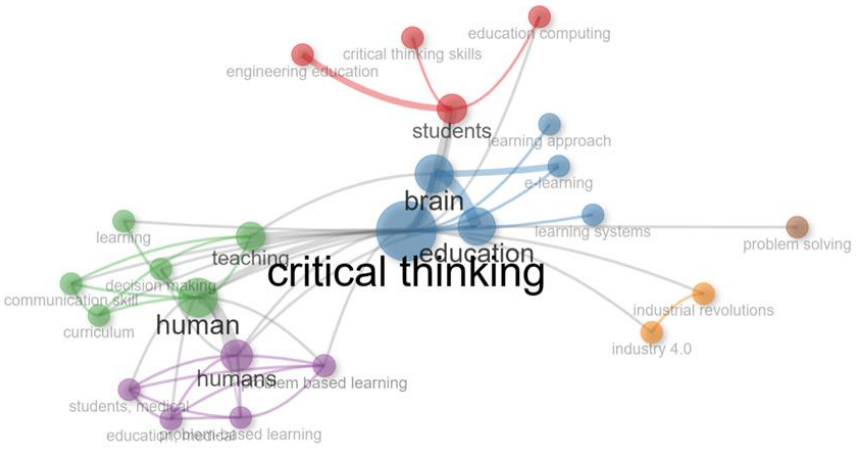

Figure 10. BRACTE Publications Intertopic Relationship Network

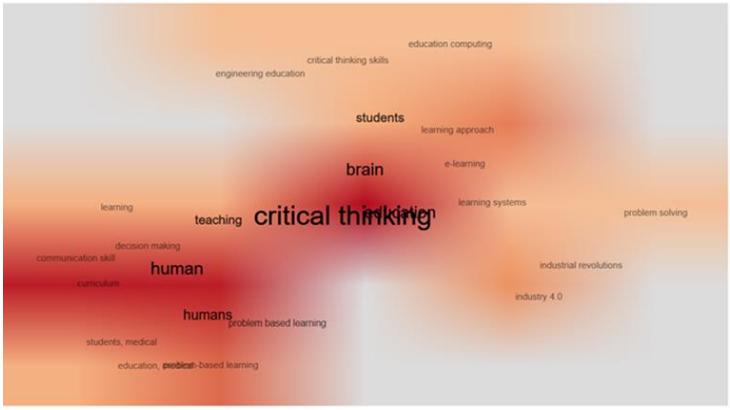

Figure 11. BRACTE Publications Density Relationship Network

The density visualization in Figure 11 shows "critical thinking" as the topic with the highest density, followed by "education," "brain," and others. Topics like "learning approach" and "communication skills" rarely appear in BRACTE publications.

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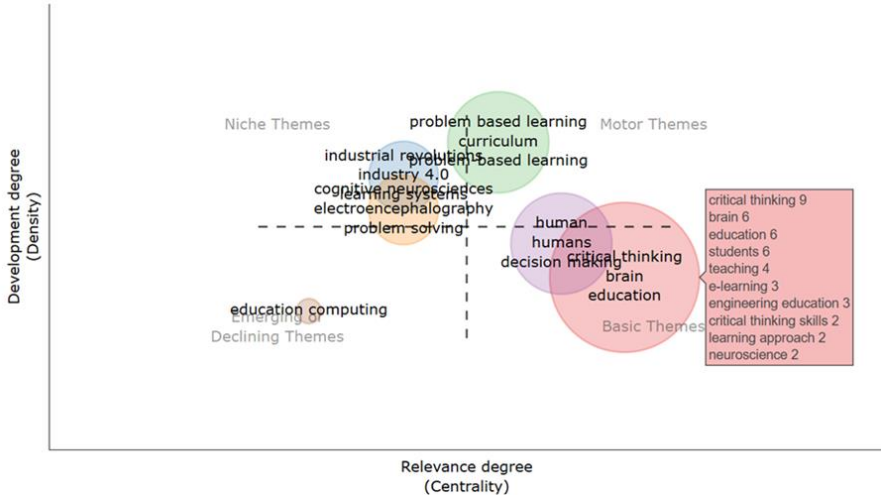

Figure 12. BRACTE Publications Thematic Map

Thematic maps are interactive instruments that allow for the visualization, exploration, and analysis of online data (Smith, 2016) by displaying the geographical distribution of certain phenomena, often related to demographic, social, cultural, or economic aspects (Tennekes, 2018). This tool effectively generates accurate, reliable, and intuitive maps, making it easy to comprehend and interpret the information presented (Vasilca, 2019). Figure 12 reveals four main themes in BRACTE publications: special, motor, emerging, and basic. The basic theme dominated with the topics of "critical thinking," "brain," and "education," followed by "students," "teaching," and "e-learning." The "education computing" issue is an emerging theme, signaling the potential for growth in BRACTE research.

WordCloud BCTE Publication Analysis

Wordcloud is a text data visualization tool that highlights words based on their frequency of occurrence (Padmanandam et al., 2021) from various sources on the internet in a context (Chandrapaul et al., 2019) with variations in font size and color in electronic images (Bafna & Saini, 2020; Kabir et al., 2020), facilitating the identification of crucial topics (Mulay et al., 2020; Philip, 2020).

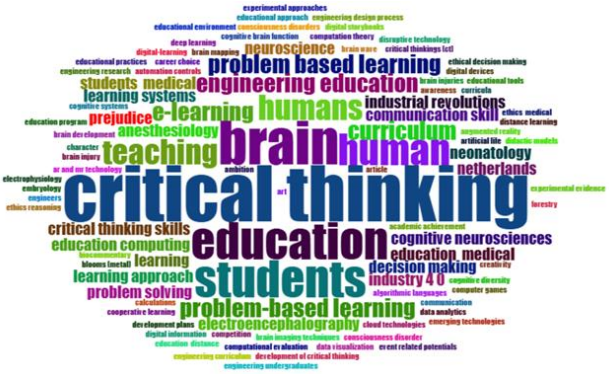

Figure 13. Wordcloud for the "keyword plus" area of BCTE publications

Wordcloud analysis of BCTE publications helps reveal keywords frequently used in the context of brain and critical thinking in education. Figure 13 shows a cloud visualization of the word " keywords plus " with the top 100 words. It can be seen that the keyword plus "critical thinking" is a keyword that is frequently used by authors in their published publications. The keyword plus with the next largest font

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size is "brain". Based on the findings, it can be seen that the integration of the keywords critical thinking and brain is often associated. Furthermore, the keywords "students" and "Education" are also keywords frequently used in BCTE publications.

Figure 14. Wordcloud for the "author keywords" area of BCTE Publications

Figure 15. Wordcloud for the "title" area of BCTE Publications

Figure 14 focuses on the “author keywords” with the top 50 words. The authors widely used the keyword “critical thinking” in BCTE publications published 2013 – 2023. Then the next most author keywords are “neuroscience”, “education”, “creativity”, higher education”, “neuroeducation”, “industry 4.0” and so on. Figure 15 shows the wordcloud for “title” with the top 100 words in the N-gram analysis using “unigram”. N-gram is an analysis method that parses a series of words to extract phrases or keywords relevant to the title or subject targeted by the author (Ojo et al., 2021).

Conclusion

The findings from the analysis of Scopus publication data for the period 2013-2023 in Table 4 regarding the frequency of BCTE publication topics are seen for the topic of critical thinking continuing to increase from year to year and becoming a keyword frequently used in publications related to the brain and critical thinking in the wordcloud analysis with the largest font size. This also aligns with the network analysis, which shows that "critical thinking" is the main topic mainly integrated with the brain and education. However, publications that integrate brain-based learning with critical thinking are still very limited in the educational literature. Further research is needed on media, assessment, and evaluation that support brain-based learning to enrich students' critical thinking skills.

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Research that combines brain-based learning, critical thinking, and creativity to improve 21st-century skills is also limited. The relationship between brain-based learning and critical thinking with fun and effective learning methods must be explored more deeply. Understanding how the brain works will enable educators to design a comprehensive learning plan, including teaching materials, implementation, media, models, strategies, approaches, and appropriate methods, to achieve learning goals.

Bibliometric analysis effectively evaluates scientific work and uncovers relevant evidence in a field. Literature surveys play a role in identifying knowledge gaps. The reports often contain up-to-date information on research directions and author collaborations that indicate their interest. In BCTE research, universities contributed more than companies, with the United States as a significant contributor from 2013 to 2023. Indonesia is seventh with four publications, including the work of Susanti et al. (2019), which improved students' critical thinking skills through brain-based cooperative learning for logarithmic materials.

The analysis of BCTE publications is limited to data from Scopus between 2012-2023 and does not contain added databases such as Web of Science or Google Scholar. Keywords can be adjusted to find new knowledge gaps. English is the primary analysis language but can be changed as needed. Scopus secondary records serve as additional data. As a result, this BCTE research still needs to be evaluated using various databases and languages to be more precise and extensive.

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