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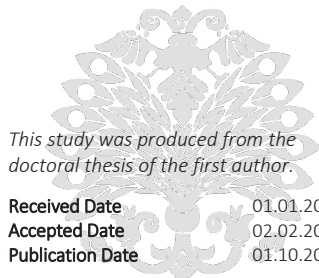


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Study on Brainstorming from 1981 to 2022 in Education: A Bibliometric Analysis

ABSTRACT

This research was conducted to analyze the application, utilization or use of the brainstorming technique in the education field. The aim of this study is to examine the studies published on the brainstorming technique with bibliometric analysis and to determine and evaluate the publications, trends, citation relationships etc., followed in this field. Bibliometric analysis is used to identify the current status of research and the critical points in bibliometric data mapping can help predict future research trends, so it is aimed to benefit scientists doing research in these fields and to produce usable data by providing statistical information on the basis of publications, authors, sources, institutions and countries. Therefore, this study presents the general, conceptual, intellectual and social structure of the brainstorming technique. In this context, 305 articles on the brainstorming technique published in the WoS database between 1981 and 2022 were analyzed through the R program. According to the analysis results, 803 authors used the brainstorming technique in their research in 218 different journals. Additionally, an average of 9.06 publications were made annually, and 15.14 citations per article were made to these publications annually. Among these studies, the author who published the most on the brainstorming technique was Paulus PB. Creativity Research Journal has the most articles published, with 14 publications. The most frequently used words by the authors are "brainstorming" (n=43) and "creativity" (n=41). In terms of countries, the most publications were made in the United States of America.

Keywords: Bibliometric analysis, brainstorming, social network analysis, trends, education

Introduction

As time progresses, individuals' desire and curiosity to learn continue to increase, leading to the discovery of various methods, strategies, and practices aimed at fostering meaningful learning. In this context, the methods, strategies, and techniques applied both inside and outside the classroom should serve to facilitate meaningful learning for students and play a significant role in ensuring the permanence of acquired knowledge. The brainstorming technique is widely used in many fields, including education. A review of the literature reveals that this technique is actively employed in classroom environments (Al-Bayati & Mizban, 2022; Masri, 2019; Pérez Sánchez, 2023; Putman, 2001; Sutisna et al., 2022; Wagbara, 2020). However, there are both advantages and limitations to its use in classroom settings.

Humans have lived as beings who think since the dawn of

humanity. These thought processes have evolved in many different ways. One of these is the effort to solve problems by coming together, presenting different ideas, discussing, and generating creative solutions. The brainstorming technique, first developed in the 1940s by Alex F. Osborn, has since evolved to play a critical role in educational settings, particularly in enhancing cognitive processes such as creative problem-solving and collaborative learning. Osborn first introduced this technique in his book "Your Creative Power," published in 1948. In his book, he suggested that bringing people together in groups to freely generate ideas could help them find creative solutions (Osborn, 1948). Since Roger Sperry won the Nobel Prize in Medicine in 1981, the identification of the relationship between the brain and learning has become easier, and the brainstorming technique has begun to be tested and subsequently spread (Diehl & Stroebe, 1987; Paulus & Dzindolet, 1993; Petrovic & Krickl, 1994; Romizowski, 1986).

In the information age, there is a need for creative and productive individuals who know how to access new information, who question, examine, analyze and transfer information, and who have problem-solving skills. It is important to restructure education and training environments to adapt them to 21st-century skills (Nakiboglu, 2003). People's desire and curiosity for learning lead to the discovery of different ways, methods and applications in order to achieve meaningful learning. For these reasons, the methods, strategies, and techniques to be applied inside or outside the classroom should play a role in facilitating meaningful learning for the student and should be useful in ensuring permanence (Gul, 2013). The brainstorming technique is based on the ability of individuals to easily express what is on their mind about a topic or problem without any restrictions, and it can also contribute to the development of individuals who think creatively and can express themselves easily (Ocak, 2007; Osborn, 1957). This technique can also be described as a method used to generate solutions to the problems students face in today's world, supporting the development of creative (Alrubai, 2014; Isaksen & Gaulin, 2005; Karatas & Tonga, 2016; Kaya, 2021; Masri, 2019; Rao, 2007; Taleb vd., 2013), critical, analytical (Nakiboglu & Altiparmak, 2002), lateral, etc., as 21st-century thinking skills (Alrubai, 2014; Nakiboglu, 2003; Ozden, 2003).

Brainstorming in Education

Osborn (1957) claimed that the brainstorming technique is used in group problem solving and significantly increases the number and quality of ideas generated in groups. According to Hoing (2001), the brainstorming technique is used to reveal new and wonderful ideas by expanding existing knowledge with new connections, and Wosu (2023) defined this technique as a conference that develops students' group creativity together and enables students to solve daily life problems, given fair sharing and freedom of expression. At the same time, brainstorming is an innovative strategy that can be defined as a technique to obtain a large number of ideas on a specific subject from a group of people in a short time (Obafemi, 2024; Rawlinson, 1981), an effective technique in generating numerous good ideas (Grossman et al., 1989) and an activity aimed at developing creativity and acquiring discussion skills for analyzing thoughts (Alrubai, 2014; Kumar, 2021; Masri, 2019; Obafemi, 2024; Orlich et al., 1990; Rao, 2007; Taleb et al., 2013).

Brainstorming enables students to actively use their cognitive skills, think creatively, and solve problems analytically (Hassanein, 2002; Hoing, 2001; Mohammad, 2016). Teaching-learning environments become more attractive and appealing with the brainstorming technique.

The aim of this technique is to encourage students to participate more in class (Wosu, 2023), to learn more easily, and to make the learning environment enjoyable. Communication in the classroom is multidirectional with the use of this technique, occurring within groups, between the teacher and students or among students (Hurt, 1994; Wahib & Zidane, 2001). Furthermore, this technique enhances students' teamwork skills (Hassanein, 2002). Students who can share their feelings and thoughts without criticism in class will feel comfortable and motivated in other lessons as well, and they will be able to express themselves and their thoughts easily in any environment.

Brainstorming has both advantages and disadvantages, like many practices. In educational contexts, according to Obafemi (2024), brainstorming offers various benefits such as enhancing problem-solving skills, developing critical thinking abilities, facilitating idea generation, fostering interaction with teachers, practicing active listening, providing opportunities to develop ideas under teacher guidance, generating new ideas, increasing student interest in lessons, encouraging participation, and supporting long-term learning processes (Wahib & Zidane, 2001; Wosu, 2023). It is a method that appeals to cognitive and affective characteristics, allowing individuals to express themselves comfortably (Obafemi, 2024). Moreover, according to Isaksen and Gaulin (2005), this technique is the most well-known and used technique related to creative problem-solving and creativity. The most important advantage in the education field is that the effective and efficient use of the brainstorming technique holds significant importance in influencing students' academic achievements (Aini, 2022; Ibnian, 2011; Odoh, 2013). However, brainstorming also has its limitations. For instance, it can hinder the participation of quiet students in some cases, lead to uneven group interactions or pose challenges for certain students in generating creative ideas. Additionally, there may be variability in the quality and applicability of ideas generated through brainstorming. In conclusion, while brainstorming offers many advantages in education, it is important to be mindful of its limitations when implementing this method. Therefore, adopting a balanced approach during application is crucial. In addition, according to Osborn (1957), it is claimed that an individual within a group generates twice as many thoughts compared to when they are alone. However, some studies have found the opposite (Taylor et al., 1958). The total number of thoughts produced in face-to-face brainstorming groups was found to be less than the number produced individually. According to Diehl and Stroebe (1987), in groups where there is minimal group interaction and members work individually, the number of

thoughts produced is found to be twice as much compared to groups with higher interaction. Based on these studies, it can be concluded that individuals working alone produce thoughts more efficiently. Additionally, groups are also considered as energy drains in brainstorming (Isaksen, 1998).

The brainstorming technique is employed as a discussion method designed to motivate students and facilitate their active participation. It begins with a problem statement presented by the teacher, followed by the generation of solutions by the students. The core principles guiding the use of this technique include: the absence of criticism (Coon, 1983), the encouragement of unrestricted thinking, the emphasis on quantity over quality, thereby promoting the generation of numerous ideas to arrive at a solution, the emergence of diverse ideas through the combination of different thoughts (cross-pollination), and the recognition of every idea as valuable and unique (Knowles, 1990; Osborn, 1957).

When utilizing this technique in the classroom, the first step involves creating a democratic environment, motivating students, and ensuring their attention is focused. In the second stage, the rules are reiterated, and necessary information is provided. The third stage involves presenting the question, problem, or need (warm-up), followed by the formation of groups (5-12 people) in the fourth stage, where suggestions are written on the board and active participation is encouraged. A time limit is crucial. Similar ideas are grouped under a single category, and there is no obligation to reach a definitive conclusion—the goal is to generate as many ideas as possible. In the fifth stage, votes are cast to reduce the number of suggestions. In the sixth stage, the ideas receiving the most votes are circled. The seventh stage involves evaluating and discussing the suggestions, and in the eighth stage, a final vote is conducted, and the results are announced (Byron, 2012; Osborn, 1957; Rawlinson, 1995).

According to several studies, the use of visual stimuli during the implementation of the brainstorming technique has been shown to increase idea generation, support creativity, and contribute to the emergence of higher-quality thoughts (Coskun et al., 2015; Gocmen & Coskun, 2022; Nijstad et al., 2002; Yang & Lee, 2020; Yuksel & Coskun, 2023). Based on these findings, the use of visuals or the integration of digital tools into the brainstorming technique in classroom settings can be significant in enhancing the effectiveness of the technique (Gong et al., 2022).

Purpose of the Study

The main reason for selecting this technique within the scope of this research is the belief that, despite its widespread popularity and extensive use in the field, it has

not been fully understood and has not been extensively studied in detail. From this point of view, it has been seen that it is necessary to look at the studies related to this technique from a broad perspective, to identify trends, to examine this technique from general, conceptual, social and intellectual perspectives, and to evaluate whether this technique is sufficiently effective by examining the studies carried out on the keywords that emerged on the conceptual structure of the studies in the literature. Through bibliometric analysis, it examines trends and current developments, assessing how studies have varied over time, identifying emerging topics and trends, and exploring regional and institutional inclinations. Furthermore, citation analyses and evaluations of scientific impact are conducted. As a result, to offer a broad perspective on the brainstorming technique, thereby providing researchers with deeper insights and guidance for future studies. In this context, the main aim of this study is to conduct a bibliometric evaluation of articles published on the brainstorming technique, determining and evaluating the publications, citation relationships, and trends followed in this field. Additionally, by providing statistical information on publications, authors, sources, institutions, and countries, it aims to benefit researchers in this field and generate data that can be used in scientific publication policies. It is believed that the study, by compiling literature knowledge related to the brainstorming technique and serving as a reference for researchers interested in the field and considering research, will fill the gap in the field by indicating important publications, authors, institutions, sources, and countries.

In this context, the problem statement and sub-problems of the research are as follows:

1. What are the evolutionary trajectory and emerging research trends in studies on the brainstorming technique?
 - a) What are the fundamental characteristics that define the general structure of the brainstorming technique within the existing literature?
 - b) How has the conceptual framework of the brainstorming technique developed over time, and what are the key themes and topics that dominate this conceptual landscape?
 - c) How does the social structure of the brainstorming technique research community manifest through collaboration networks, co-authorship patterns, and institutional affiliations?
 - d) What is the intellectual structure of the brainstorming technique research field, as reflected by influential authors, foundational theories, and prominent research clusters?

Methods

Research Model

In this study, we adopted the methodological approach of combining bibliometric examination and systematic literature review as previously applied by Dabić et al. (2020). The research process was further structured in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al., 2009), ensuring a rigorous and transparent review process. According to Caputo et al. (2018), the concurrent use of bibliometric analysis and systematic literature review methods is regarded as the most effective strategy for advancing scientific knowledge. These two methodological approaches serve complementary purposes by facilitating the comprehensive exploration and development of scientific knowledge within a specific research domain. While bibliometric analysis offers a quantitative lens for evaluating patterns and trends in the literature, systematic literature review provides a qualitative perspective that enables an in-depth assessment of subjects and content (Hallinger & Wang, 2020). Thus, the integration of these approaches provides a robust framework for conducting detailed and holistic analyses of the research field.

Adopted methodology for the systematic literature review

In this study, a systematic literature review was conducted to provide an in-depth exploration of the research topic, which focuses on the brainstorming technique. This method is utilized to collect data based on predefined criteria for a specific research area (Suyo-Vega et al., 2022) and is widely employed across various disciplines (Asadi & Dahlan, 2017). During the systematic review phase, the existing literature on brainstorming techniques was rigorously analyzed using the Web of Science (WoS) database (Higgins & Green, 2011). Initially, relevant keywords and criteria were identified from the literature, and the inclusion and exclusion processes were meticulously defined. To further refine the search procedure and identify bibliometric trends, the integration of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) analysis was deemed necessary (Moher et al., 2009). PRISMA provides a set of guidelines aimed at enhancing the transparency and reproducibility of systematic reviews. The study phases and inclusion process of the articles were visually presented using the PRISMA flow diagram, which clearly illustrates the studies that were accessed, excluded, and ultimately included at each stage of the research process. The integration of PRISMA enhances the transparency of the study and ensures methodological rigor (Liberati et al.,

2009).

The data exclusively were obtained from the Web of Science (WoS) database, which may have limited the study's scope by excluding relevant studies from other databases such as Scopus and PubMed. One of the most important reasons for choosing the WoS database is that the downloaded file extension is integrated with the R program used to analyze the data. Moreover, WoS is a multidisciplinary database that provides comprehensive and reliable indexing of academic publications worldwide, adhering to high-quality standards. Due to its high citation impact and international visibility, WoS is frequently referenced as a primary source for bibliometric studies (Falagas et al., 2008). Additionally, WoS offers advanced filtering and analysis tools that enable detailed examination of publications by year, subject area, author, and institution. These features allowed this research to accurately and reliably reveal trends within the scientific literature. Furthermore, the regularly updated and extensive coverage of WoS ensured inclusion of both recent and historically significant publications related to brainstorming techniques.

Furthermore, only articles indexed in the WoS database and published between 1981 and 2022 were included, constituting another limitation of this study. The details of the inclusion and exclusion criteria for the studies can be found in Table 1, and the identification and screening process of the included articles are illustrated in Figure 1

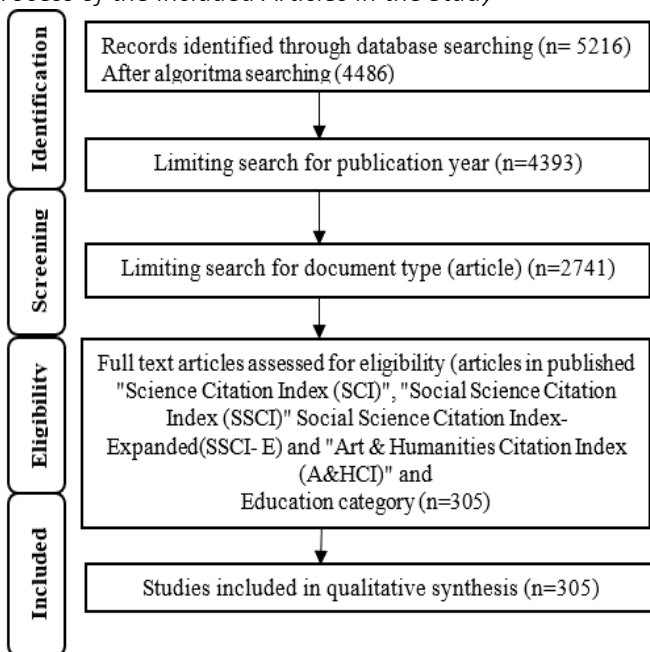
Table 1.	
Inclusion and Exclusion Criteria for the Studies	
Inclusion Criteria	Exclusion Criteria
Includes the concept of brainstorming technique	
Covering the period between 1981 and 2022	Studies carried out in 2023
WoS database (algorithm limitation)	Other databases
Studies in prestigious and scientific indexes or databases (WoS)	Editorial material, conference papers, early access, review article, book, book chapters, letter, note, meeting abstract
"education" field restriction	
Full text article	

using the PRISMA flow diagram.

A search was conducted in the WoS database using the keyword "brainstorming," yielding a total of 5,216 studies between 1980 and 2023. The WoS database's "Topic" field searches for keywords within the title, abstract, author keywords, and Keyword Plus. Keyword Plus is generated from the titles of the references in the studies using a computer algorithm to identify the most frequently recurring words or phrases (Garfield, 2004). However, Keyword Plus is considered less comprehensive than the Author Keyword field in determining the content of a study (Zhang et al., 2016). Therefore, the detailed search section in the WoS database was restricted to the Title, Abstract, and Author Keyword fields, using the algorithm ((TI=(brainstorming)) OR AB=(brainstorming)) OR AK=(brainstorming)), which resulted in 4,486 studies. To align with the research objectives, only articles were selected for analysis, while editorial materials, conference papers, early access, review articles, books, book chapters, and notes were excluded. Subsequently, the subject area was narrowed to "Education," resulting in a final dataset of 305 studies published between 1981 and 2022. Figure 1 provides an overview of the study selection procedure following the PRISMA approach.

Figure 1.

PRISMA Flow Diagram of the Identification and Screening Process of the Included Articles In the Study



Adopted Methodology For The Systematic Literature Review

For the bibliometric analysis, we adopted a methodological framework based on bibliometric techniques (Zupic &

Čater, 2015). This quantitative method is used to analyze and evaluate scientific publications and other written forms of communication. Through bibliometric analysis, the structure and content of the studies are examined (Cheng et al., 2018), making it a widely applicable tool across all fields (Abumalloh et al., 2022). The bibliometric approach was selected due to its capability to conduct an in-depth analysis and reveal the development of the topic within the field. This analysis evaluated both the qualitative and quantitative aspects of the literature, examining factors such as publication numbers, citation counts, authorship, country contributions, and research trends (Mas-Tur et al., 2020; Pritchard, 1969; Van Eck & Waltman, 2010). The study also conducted co-citation, co-occurrence, and keyword analyses to explore connections between topics, disciplines, knowledge, and individual studies (Bellia et al., 2022). The general, conceptual, intellectual, and social structures of the brainstorming technique were analyzed using the R package. Consequently, the integration of these methodological approaches is expected to significantly contribute to understanding the overall status of the literature and to guide future research in the field.

Results

The findings of the study have been examined under two main headings for a more meaningful presentation. The headings are named according to bibliometric types and analyses.

Descriptive Bibliometry

General Structure Analysis

In this section of the study, fundamental information regarding the brainstorming technique has been provided. As a result of the analysis of criteria related to the brainstorming technique, based on data obtained through the "biblioshiny" web interface of the bibliometrix package in the R programming language, a total of 305 articles published in 218 different journals in the WoS database covering the period from 1981 to 2022 were identified. Statistical information about the research data is presented in Table 2.

Table 2.

Basic Statistical Information on the Subject Area

Findings	Results
Examined Time Period	1981-2022
Sources	218
Documents (Number of Articles)	305
Annual Growth Rate %	9.06
Average Age	9.43

Average Number of Citations per Article	15.14
References	9857
Document content	
Keywords (ID)	460
Authors' Keywords (DE)	896
<i>Authors</i>	
Authors Average	803
Number of Single-Author Articles	67
Number of Co-Authors per Article	2.88
Collaboration Index %	15.74

According to Table 2, articles published in the WoS database in the relevant time period related to this concept received an average of 15.14 citations. Additionally, it was determined that 803 authors contributed (cited) to the brainstorming technique 9857 times. The number of single-authored articles is 67, and the number of co-authors per article is 2.88, and the collaboration index is 15.74. The annual production rate has shown an increasing trend over the years, and the annual growth rate has been analyzed as 9.06%.

Table 3.

Number of Articles by Year

Year	Article	Percentage %
1981	1	0.32
1982-1991	7	2.29
1992-1996	8	2.62
1997-2001	15	4.91
2002-2006	15	4.91
2007- 2011	50	16.39
2012-2016	66	21.63
2017-2022	143	46.88
Total	305	100

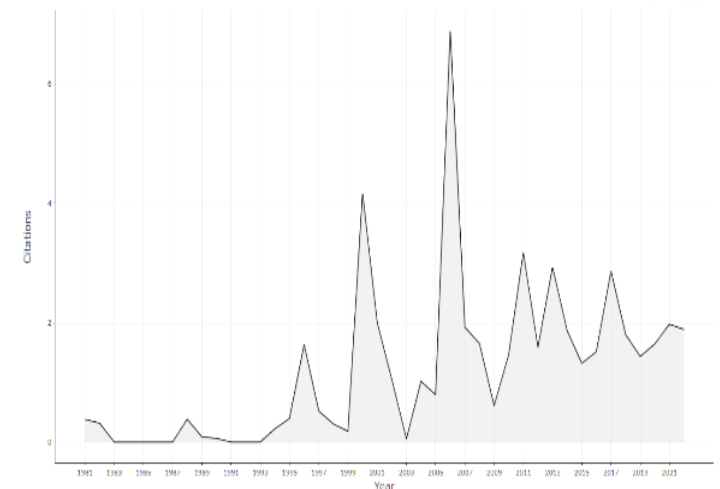
According to Table 3, the production of studies on the subject continues at an increasing pace. No study on the subject was carried out between 1984-1988 and 1990-1994. In addition, as seen in Table 3, scientific production continued to increase in a fluctuating manner in increasing and decreasing curves within the scope of the subject area as of 1996. As of 2009, scientific production continued without any decrease.

According to Table 3, it can be observed that the first study related to the brainstorming technique began to be published in 1981. The initial study, published in 1981 (1 article) in "Applied Psychological Measurement," is the work of Forbach, G.B., and Evans, R.G., titled "The Remote Associates Test as a Predictor of Productivity in

Brainstorming Groups." It is noted that the highest number of articles in the relevant field is in 2022, with 35 studies. Additionally, it is observed that articles published after 2017 constitute 46.88% of the total articles. The annual average citation count for the subject area is shown in Figure 2.

Figure 2.

Annual Average Number of Citations



Upon examining Figure 2, the citation rate is 0.38 in 1981 and 1988. It reached 1.63 in 1996. In 2000, it reached 4.16, and in 2006, it reached 6.88, reaching its highest values. In 2007, it was 1.92, in 2008, it was 1.65, in 2011, it was 3.17, in 2013, it was 2.92, in 2017, it was 2.86, and in 2022, it was 1.89. It is evident that articles published in 2000 and 2006 in the relevant subject area received more citations than in other years.

General Information About Sources

While attempting to determine the most effective sources, the number of publications, citations, total citation counts, total publication counts, and h-index values of the journals were evaluated. The h-index is an evaluation criterion created to understand the publication activity and effectiveness of published works of a journal or author (Al, 2008). For this purpose, the analysis of the h-index in this study aims to understand which journal's published articles are more effective. Journals or authors with longer academic careers may have higher h-index values (Bornmann et al., 2008). The most active sources in terms of publications related to brainstorming technique and the journals receiving the most citations in this field are presented in Table 4.

Table 4.*Journals with the Most Publications in the Field*

Journals	Articles
Creativity Research Journal	14
Thinking Skills and Creativity	13
Journal of Creative Behavior	8
Educational Technology \& Society	5
Education Sciences	4
International Journal of Technology and Design Education	4
British Journal of Educational Technology	3
Computers \& Education	3
Computers In Human Behavior	3
Frontiers In Psychology	3

When the journals are examined, the articles are published in 218 different journals and the journal that publishes the most in the field is Creativity Research Journal (n=14). 13 articles were published in the Thinking Skills and Creativity journal and 8 articles were published in the Journal of Creative Behavior. Moreover, the most cited source among the journals is J Pers Soc Psychol (n=291). Creativity Research Journal (n=14), the source where the most articles are published, ranks 2nd with 241 citations. Journal of Creativity Behavior ranks 3rd with 155 citations. Thinking Skills and Creativity ranks 7th with 91 citations.

Table 5.*Source Impact of the Top 5 Most Published Journals*

Journal	h index	g index	m index	TC	NP	Year of Publication
Creativity Research Journal	8	14	0.308	416	14	1998
Journal of Creative Behavior	6	8	0.143	149	8	1982
Thinking Skills and Creativity	6	10	0.353	108	13	2007
Educational Technology \& Society	5	5	0.333	103	5	2009
Computers In Human Behavior	3	3	0.250	214	3	2012

Table 5 contains information about the h-index and g-index of the top 5 journals containing articles on the brainstorming technique. When the sources were ranked in terms of h index, it was analyzed that Creativity Research Journal had an h-index of 8, Journal of Creative Behavior

had 6, and Thinking Skills and Creativity had 6. It was analyzed that the Creativity Research Journal on the brainstorming technique between 1981 and 2022 was effective in terms of h, g, TC and NP values. The total citations are Creativity Research Journal (TC: 416), Personality and Social Psychology Review (TC: 359), Computers in Human Behavior (TC: 214). The total number of articles in the journals is Creativity Research Journal (NP: 14), Thinking Skills and Creativity (NP: 13).

Bradford law was created by Samuel C. Bradford in 1934. In this law, journals containing studies related to the subject area are divided into three core groups. Journals in the small core group are few in number and contain important publications in the field (Garfield, 2004). The small group is the most effective group for the subject area. Among these journals, it has been determined that Creativity Research Journal (n=14) is the most productive journal with more coverage in basic resources about the "brainstorming" technique than other journals. This journal is followed by Thinking Skills and Creativity, Journal of Creative Behaviour, Educational Technology & Society, Education Sciences.

It also appears that these journals are similar to the list of journals with the highest number of publications. It is analyzed that these core sources published approximately 33% of the articles in the collection, with a contribution of 101 articles. In the medium region, there are 92 sources with contributions of 104 articles, while in the small region, there are 100 sources with contributions of 100 articles.

General Information for Authors

In the author analysis, the number of publications of the authors by year and the h-index were taken into account. These findings are presented in Table 6.

Table 6.*The 5 Authors who Produced the Most Articles in Their Subject Area*

Author	Article
Paulus Pb	5
Coskun H	4
Kohn NW	4
Nijstad Ba	4
Rietzschel Ef	4

According to the criteria analysis related to the brainstorming technique, a total of 803 authors contributed to the field (Table 2). Upon examination of Table 6, it is analyzed that the authors who produced the most articles on the subject during the analyzed period are Paulus PB. (n=5), Coskun H. (n=4), Kohn NW. (n=4), Nijstad

BA. (n=4), Rietzschel EF. (n=4), Stroebe W. (n=4), and Wang Cc. (n=4). Among these authors, Paulus PB. is affiliated with the University of Texas at Arlington, while Coskun, H. is affiliated with Abant Izzet Baysal University. When the author impacts based on citation counts are examined, it is analyzed that the most cited authors are Nijstad BA. (n=43), Stroebe W. (n=43), and Rietzschel EF. (n=20). It is analyzed that Jamet E, Le Henaff B, Metayer N, and Michinov N. have the same citation count (n=9). Having the same citation count among authors is an indication that they have collaborated on the same article. Nijstad BA., Stroebe W., and Rietzschel EF. are affiliated with Groningen University. It is generally analyzed that the mentioned authors have collaborated. Figure 3 illustrates author productivity through Lotka's law.

Figure 3.
Author Productivity Graph via Lotka's Law

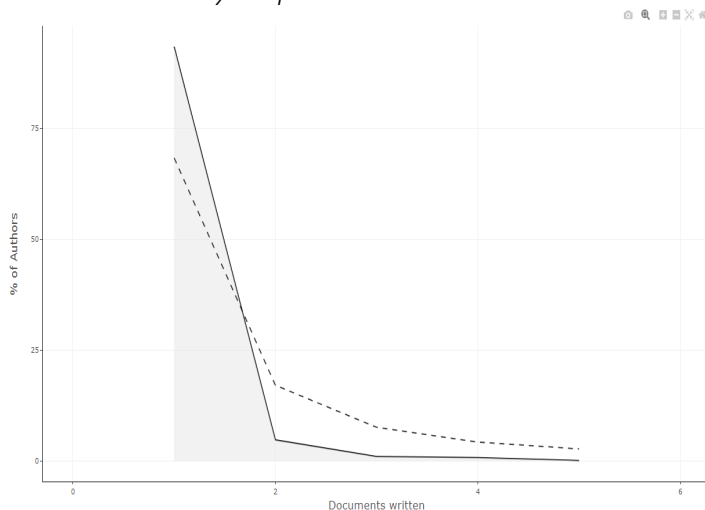


Figure 3 represents the dashed curve, which represents the graph according to Lotka's law. The dashed line represents the theoretical distribution, while the solid line represents the observed distribution. According to the figure, it is concluded that 93% (n=750) of the researchers conducting studies on brainstorming techniques have only published one article, while the proportion of authors with two publications is 3% (n=38). It is observed that 0.18% of researchers have published between 3 and 5 publications in the field (n=15). According to Lotka's law, the ratio of researchers contributing with a single publication to all publications in the field should be 60% (Lotka, 1926). Accordingly, the articles related to the brainstorming technique published in WoS do not comply with Lotka's law. When examined Authors' g, m, and total indices, in terms of the h-index, it is analyzed that Paulus PB has the highest

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h-value (n=5). Then, it is analyzed that Kohn NW., Nijstad BA., Rietzschel EF., and Stroebe W. have the same h-values (n=4). In terms of the g-index, it is also analyzed that the rankings of all authors listed in the h-index have the same g-index values. Additionally, Coskun H and Wang Cc authors have a g-index of 4. According to the total citation index, Nijstad BA. and Stroebe W. stand out with a clear lead with 664 citations each. Rietzschel EF has 315 citation counts. Following them is Kohn NW. (n=236), and Amabile TM and Kurtzberg TR are authors with the same number of citations (n=214). Furthermore, the fact that Nijstad BA. (n=664) and Stroebe W. (n=664) have the same citation count is due to their collaboration as co-authors on the same article titled "How The Group Affects the Mind: A Cognitive Model of Idea Generation in Groups," published in "Personality and Social Psychology Review" in 2006. Nijstad BA., Stroebe W. and Rietzschel EF, who work at the same university, have also collaborated on articles titled "Relative Accessibility of Domain Knowledge and Creativity: The Effects of Knowledge Activation on the Quantity and Originality of Generated Ideas" in 2007 and "Beyond Productivity Loss in Brainstorming Groups: The Evolution of a Question" in 2010.

General Information for Universities

Table 7 below lists the top 5 universities with the most articles based on the data obtained regarding the brainstorming technique.

Table 7.
The Top 10 Universities with the Most Articles based on the Data Obtained regarding the Brainstorming Technique

University	Article
Natl Taiwan Normal University	16
Calif Los Angeles University	11
Texas Arlington University	11
Indiana University	10
Hong Kong University	10

According to Table 7, it was analyzed that the universities with the most publications in terms of brainstorming technique were Natl Taiwan Normal University (n=16), Calif Los Angeles University and Texas Arlington University (n=11).

General Information for Countries

According to corresponding authors' countries and MCP and SCP Rates, the countries of the responsible authors conducting studies related to the subject area are analyzed. Articles produced by researchers in the same country are

referred to as SCP (Single Country Publications), while articles produced by researchers from multiple countries together are termed MCP (Multiple Country Publications). The sum of a country's SCP and MCP values gives the total number of articles from that country. Accordingly, the highest contribution is analyzed from the United States (n=93), followed by China (n=27), the Netherlands (n=16), and Türkiye (n=13). In terms of SCP and MCP values, the data for the United States is as follows: SCP: 89, MCP: 4; for China: SCP: 23, MCP: 4; for the Netherlands: SCP: 16, MCP: 11; for Türkiye: SCP: 13, MCP: 0; for France: SCP: 5, MCP: 6; for the United Kingdom: SCP: 9, MCP: 2; and for Canada: SCP: 6, MCP: 3. Further examination of countries with the lowest MCP ratios reveals that Israel, Pakistan, India, Nigeria, and Cyprus each have one publication (n=1). Table 8 displays the countries with the highest citation rates.

Table 8.
Most Cited Countries

Countries	Total Citation	Average Citation
USA	2027	21.80
Netherlands	896	56.00
China	359	13.30
Germany	181	22.63
Israel	133	19.00
Austria	121	60.50
France	119	10.82
United Kingdom	118	10.73
Australia	97	12.13
Türkiye	89	6.85

According to Table 8, it is analyzed that the most cited countries are the United States (n=2027), the Netherlands (n=896), and China (n=359). In line with the data obtained from the brainstorming technique, it can be reviewed that the country that produces the most articles is the United States of America (n=270). It was analyzed that after the USA, China (n = 112), the Netherlands (n = 54), England (n = 37) and France (n = 35).

General Information in terms of Articles

Table 9 lists the most cited articles on a global scale.

Table 9.
Most Cited Articles on a Global Scale (n=5)

Article, Year, Journal	Total Citations	TC Per Year	Normalized Total Citations
Nijstad Ba, 2006, Pers Soc Psychol Rev.	359	19.94	3.07
Kurtzberg Tr, 2000, Creativ Res J.	214	8.92	2.24

Rietzschel Ef, 2007, J Exp Soc Psychol	192	11.29	6.24
Cen H, 2006, Intelligent Tutoring Systems	171	9.50	1.46
Landers Rn, 2017, Comput Hum Behav.	162	23.14	9.43

According to Table 9, Nijstad Ba's (2006) study titled "How the group affects the mind: a cognitive model of idea generation in groups" published in the Persian Soc Psychol Rev journal received 359 citations. When reviewing the most cited articles on the local scale regarding the brainstorming technique, the most cited article on a local basis is Pers Soc Psychol Rev. by Nijstad Ba (2006) with a total of 23 citations. The article titled "How the group affects the mind: a cognitive model of idea generation in groups" was published in the journal. Other authors of this study are Stroebe W. The same article by the same authors is the most cited study, both locally and globally.

Evaluative Bibliometry

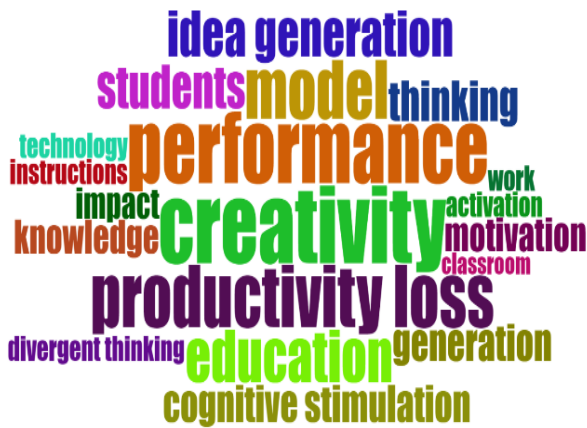
Intellectual Structure Analysis of Data Findings

Analyzes regarding the intellectual structure of the data are presented under three main headings: conceptual, social and intellectual structure analysis findings.

Conceptual Structure

The conceptual structure analyses revealed key trends such as 'creativity' and 'performance,' which are central to understanding how brainstorming techniques influence educational outcomes. However, these trends must be interpreted within the broader context of 21st-century learning frameworks. With co-word network analysis, the most frequently used words in the keywords of 305 published studies on the brainstorming technique have been identified, thus giving researchers clues about the most frequently studied topics in the subject area and the changes in these topics over the years. In addition, researchers can get clues about current trends with these keywords. The relationships and formation network of the 5 most frequently used keywords are presented in the figures. The relationships and centrality positions of the words according to their frequency of use are included in the word cloud in Figure 4. A word cloud were created for the 20 most used words and are shown in Figure 4.

Figure 4.
Word Cloud



According to Word Cloud, it is seen that the frequently used words are in the middle and large. These are "creativity", "performance" and "productivity loss" etc. Moreover, When the word tree is examined, it is seen that the word "creativity", used 25 times, covers 10%, the word "performance", used 23 times, covers 9%, and the word "productivity loss", used 20 times, covers 8%. According to trending words, it was analyzed that the words "creativity" and "performance" were trending in 2018, and the word "productivity loss" was trending in 2014. When examined from the authors' perspective, it was analyzed that the word "brainstorming" was the trend in 2016 and the word "creativity" was the trend in 2017. The most frequently used words by authors (5 words) is shown in table 10.

Table 10.
Most Commonly Used Words by Authors (5 Words)

Words	Use
brainstorming	43
creativity	41
education	16
learning	16
problem-based learning	11

When the words used by the authors are evaluated, it is understood that the words "brainstorming" (n=43) and "creativity" (n=41) are the most used words. Additionally, as a result of the analysis, the most used words in the titles were "learning" (n=66), "creativity" (n=58) and "brainstorming" (n=47), and in the summaries, "students" (n=572), "The words "learning" (n=446) and "brainstorming" (n=345) were analyzed. When evaluated in terms of usage (keywords in the database related to the subject area, plus frequently used words), it is analyzed that

the word "creativity" is the most used word (n = 25), followed by the words "performance" (n = 23), "productivity loss" (n = 20).

Figure 5.
Common Word Network

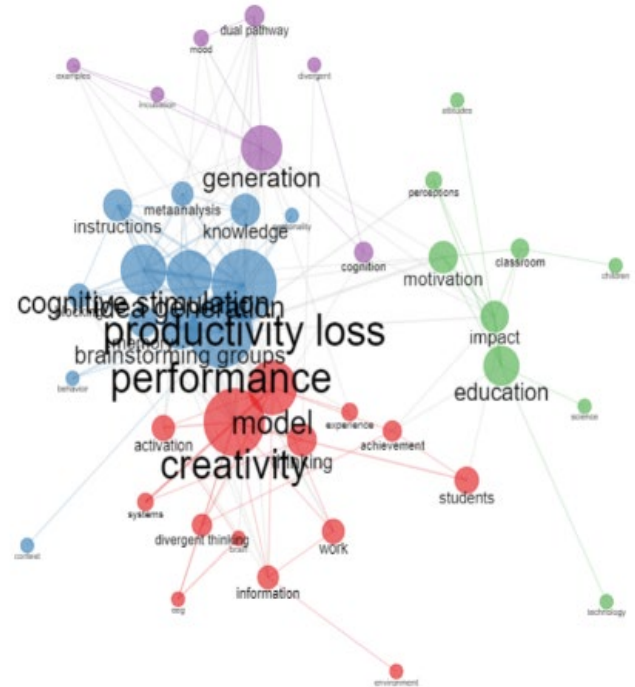
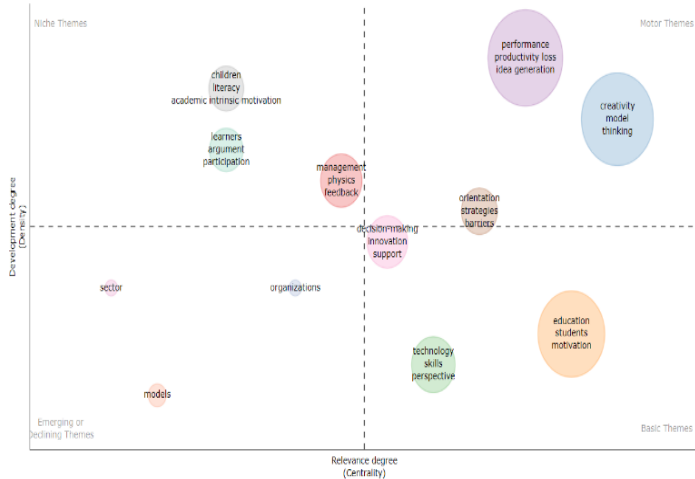


Figure 5 shows that the network map generated according to key terms consists of four different clusters of words. The first key term in each cluster has the highest centrality levels. It can be observed in the figure that there are connections between all clusters containing key terms, and these larger-sized words are frequently used together. When the data is analyzed, the key terms most commonly and jointly used with other key terms are "performance" (Betweenness: 171.9, Closeness: 0.01) and "creativity" (Betweenness: 137.49, Closeness: 0.01), both within the largest-sized red cluster. Following these words, the third-largest term is "education" (Betweenness: 121.85, Closeness: 0.009), the fourth key term is "generation" (Betweenness: 120.45, Closeness: 0.01), and the fifth key term is "productivity loss" (Betweenness: 113.12, Closeness: 0.01). It can be said that words with larger bubbles are used more frequently with other words. Additionally, it is observed that the connections between the larger-sized words are thicker. In conclusion, the frequency of repeated relationships among words within

the same cluster is high.

Figure 6.
Thematic Map



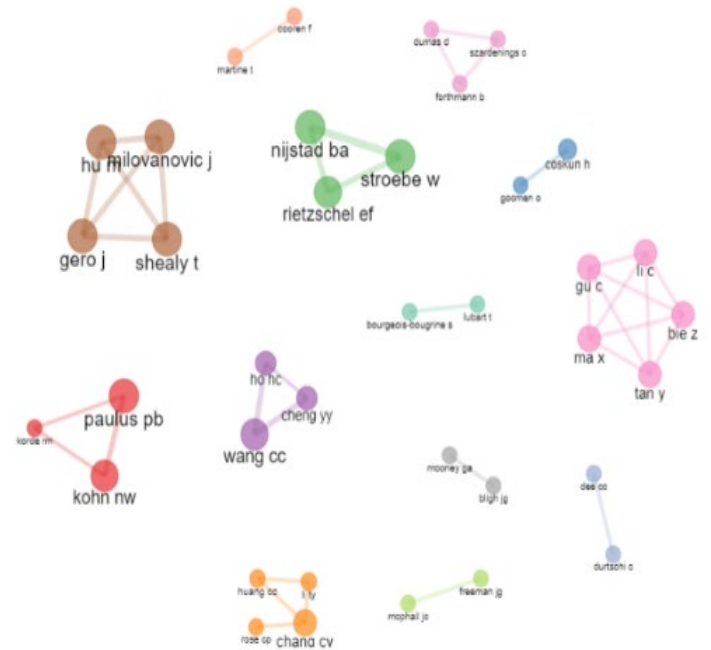
According to thematic map associated with the words depicted in Figure 6, it can be observed that clusters containing key themes such as "performance," "brainstorming groups," and "productivity loss" are present within the motor themes. Another cluster includes "creativity," "model," and "thinking." It can be said that the larger cluster is perceived to be more significant in terms of area compared to the others. In terms of location, these clusters can be considered to have above-average development and highest importance. The other smaller cluster consists of "orientation," "strategies," and "barriers." This cluster also exhibits above-average development, lies along the centrality line, and is among the significant topics.

According to simple/basic themes, clusters containing "education," "students," "motivation," intersect with the area where "decision making," "innovation," and "support" words are located, where density and centrality lines intersect. Additionally, clusters containing "technology," "skills," and "perspective" are present. Overall, when examining the map, the highest centrality continues with "creativity," "education," "performance." The highest density continues with "performance," "children," "creativity."

Social Structure

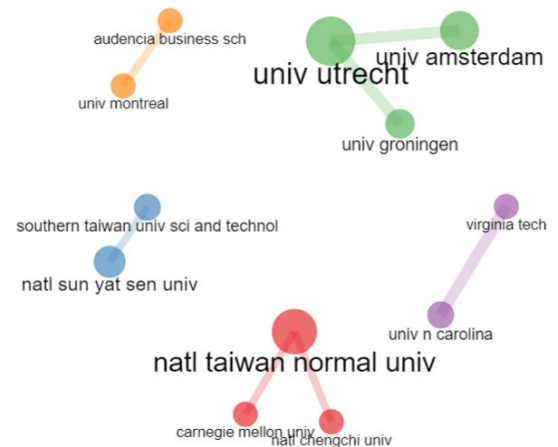
Social structure networks that emerge by focusing on collaborations between authors, institutions and countries are included in the figures.

Figure 7.
Collaboration Network of Authors



According to Figure 7, it is observed that thirteen groups of authors are collaborating. Paulus Pb and Kohn NW are the most cited authors. These authors have contributed to the study titled "Effects of Quantity and Quality Instructions on Brainstorming" (2011). Collaboration among authors can be seen in terms of network connections. Authors Nijstad BA., Stroebe W., and Rietzschel EF. In the Green cluster have a higher relationship in terms of both circle size and connection thickness. Additionally, it is known that these authors collaborate and work together at the same university.

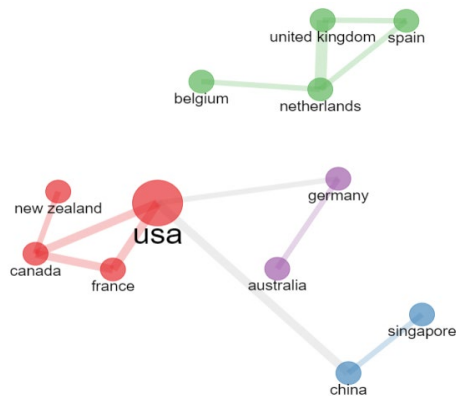
Figure 8.
Collaboration Network of Universities



In Figure 8, it is observed that five clusters are present. The university with the most collaboration among universities, located in Taiwan in the largest circle of the red cluster, is Natl Taiwan Normal Univ. Furthermore, it is observed that this university has connections with Nati Chengchi Uni. and Carneige Mellon Uni. In terms of connection thickness, it is also seen that the relationship between these universities is close. Utrecht University in the Green cluster is of the same size as Natl Taiwan Normal University. It is also observed that this university collaborates with Amsterdam University and Groningen University, and in terms of connection thickness, the relationship between these universities is close as well.

Figure 9.

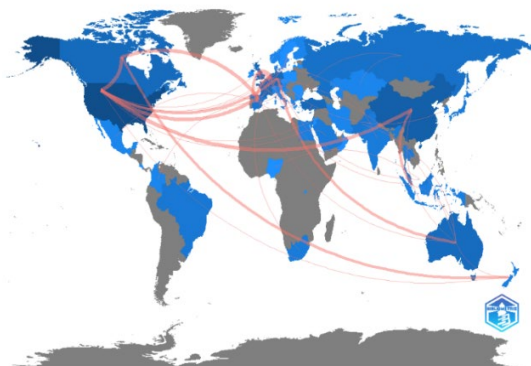
Collaboration Network of Countries



According to Figure 9, it can be said that the United States is in a central position, with a larger circle, indicating that it is the country with the most collaborations. It is observed that the United States collaborates closely with Germany in the Purple cluster and with China in the Blue cluster, along with Canada, France, and New Zealand.

Figure 10.

Collaboration Map of Countries



In the Figure 10 above, it is observed that the countries contributing the most and engaging in the most collaborations in scientific studies related to brainstorming techniques are the United States and China, represented by the darkest shade of blue. These countries are followed by Canada, Australia, Germany, the United Kingdom, and others. Collaborations between countries are shown with red lines. The analysis reveals that the United States has connections with ten countries (Belgium, Canada, China, Egypt, France, Germany, Israel, the Netherlands, New Zealand, and the United Kingdom), while the United Kingdom has connections with six countries (Austria, Germany, Greece, Italy, Spain, and Switzerland).

Intellectual Structure

Within the scope of the brainstorming technique, common citation networks for documents, authors and sources were analyzed. Co-citation analysis is a useful empirical technique to describe the intellectual structure of disciplines using an objective method (Benckendorff, 2009). As a result, the most influential journals, authors and articles are determined.

When examining the co-citation network based on articles, it is analyzed that Diehl M. (1987) has the highest number of citations and the widest network. The sequence of studies continues with Diehl M. (1987), Dugosh KI (2000), Mednick Sa (1962), Osborn A. (1957), Amabile Tm. (1983), Nijstad Ba (2002), Nijstad Ba (2010), Nijstad Ba (2006), Mullen B. (1991), Paulus (1993), and Coskun H. (2000). There is a strong network of connections among these studies. Diehl M. (1987) and Mednick Sa (1962) stand out in terms of both proximity and betweenness centrality. When examined for proximity in the other cluster, Dugosh KI (2000), Amabile Tm. (1983), Nijstad Ba (2006), Nijstad Ba (2002), Coskun H. (2000), Rietzschel Ef (2007), Paulus Pb (2007), Brown V. (1998), and Kohn NW. (2011) are analyzed. There are also similar studies in terms of betweenness centrality. Overall, it is analyzed that the articles are interconnected in terms of co-citation.

When examining the authors with more common citations include Paulus Pb, Amabile Tm., Diehl M., and Nijstad Ba. Paulus Pb, Osborn A., Nijstad Ba., and Diehl M. are analyzed to have more frequent connections. Moreover, Amabile Tm., Runco Ma., Mednick Sa., Sternberg Rj., Simonton Dk., and Guilford Jp., are located in the same cluster, are analyzed to have more frequent connections. Overall, it is analyzed that all authors are somehow interconnected and cited each other.

According to co-citation network of journal, the largest circle representing the journal with the most citations and the widest network is "J Pers Soc. Psychol." The journals "J Pers Soc. Psychol" and "J Educ. Psychol" are interconnected. In the other cluster, "Creativity Res J." and "J Creative Behav." have the widest circle. When examined in terms of proximity and closeness between clusters, the sequence is as follows: "Creativity Res J.," "J Creative Behav.," "Think Skills Creativ.," "J Pers Soc. Psychol.," and "J Educ. Psychol." The journals "Creativity Res J.," "J Creative Behav.," and "Think Skills Creativ." are interconnected.

Moreover, according to Historiograph, the first study, published by Nijstad BA. in 2006 and titled "How The Group Affects the Mind: A Cognitive Model of Idea Generation in Groups," is published in the journal "Pers Soc Psychol Rev" and ranks first with 382 citations. The second study is the article titled "Relative Accessibility of Domain Knowledge and Creativity: The Effects of Knowledge Activation on the Quantity and Originality of Generated Ideas" published by Rietzschel Ef. in 2007 in the journal "J Exp Soc Psychol," with 204 citations. The third study, authored by Stroebe W. in 2010, titled "Beyond Productivity Loss in Brainstorming Groups: The Evolution of a Question," is published in the journal "Dv Exp Soc Psychol" and has 76 citations.

Discussion

Theoretical and Practical Contributions

The bibliometric analysis of the brainstorming technique is a critical tool for understanding the theoretical and practical contributions of the method to the scientific literature (Aria & Cuccurullo, 2017; Donthu et al., 2021; Pritchard, 1969). Such analysis helps elucidate the method's contributions to the literature by enriching and advancing existing theoretical frameworks. From a theoretical perspective, the analyses facilitate a deep understanding of conceptual models related to idea generation processes and how these models operate. Practical contributions evaluate the applications of the brainstorming technique in education, business, and other fields, demonstrating how the method can be effectively utilized and under what conditions it yields optimal results. Moreover, bibliometric analyses provide guidelines for future research by highlighting the interdisciplinary impacts and potential of the brainstorming method (Pritchard, 1969). In this context, bibliometric analysis of the brainstorming technique serves as a crucial guide for researchers to deepen their understanding and utilization of the method. (Aria & Cuccurullo, 2017; Donthu et al., 2021; Pritchard, 1969).

This study is different from previous commentary on the brainstorming technique by employing an objective, systematic, and transparent analytical methodology to construct relevant research topics and identify future research directions within the domain. By analyzing cited journals, authors, articles, and keywords related to the brainstorming technique, this study enables researchers to rapidly comprehend the developmental trajectory and underlying knowledge structures of this field, thereby offering novel insights for advancing research. The review contributes to the theoretical foundation of brainstorming technique research in several ways. First, systematic bibliometric techniques were applied to investigate an extensive body of literature on the brainstorming technique, thereby identifying several core themes, such as academic performance and creativity. The identification of these themes provides new perspectives and robust evidence for a deeper understanding of the brainstorming technique. Second, unlike previous studies, this research adopts a systematic and transparent approach that facilitates the construction of relevant research topics and illuminates potential pathways for future research on the brainstorming technique. Through an in-depth analysis of cited sources and keywords, this study sheds light on the evolution and intellectual structure of this research field, which in turn serves as a foundation for generating new research ideas.

Conclusion and Implications

In conclusion, our bibliometric analysis reveals that the brainstorming technique represents a rapidly expanding research domain with several notable contributions that warrant further investigation. By utilizing the Web of Science (WoS) database and the R package, we examined various bibliometric indicators, including the annual publication count, collaboration networks (among countries/regions, institutions, and journals), and citation metrics (journals, authors, and documents). This large-scale literature analysis has enabled us to gain a comprehensive understanding of the development and research trends within the field of brainstorming. Our findings indicate that the number of publications on this topic has steadily increased, particularly since 2009, without any noticeable decline, highlighting a sustained interest in academic performance and creativity. Between 1981 and 2022, a total of 305 studies authored by 803 researchers were published across 218 journals indexed in the WoS database, demonstrating the growth and ongoing relevance of this research area.

Moreover, our analysis of the collaboration network reveals that the United States of America and the Netherlands hold a dominant position in this field, it can be said that the reason why most of the studies have been carried out in the USA is that researchers in this country are very interested in the subject area. The academic dominance of the United States in the field of brainstorming techniques is directly related to the fact that the method was first developed in the U.S. by its creator, Alex F. Osborn (Osborn, 1957). In addition, the country's substantial investment in research and development, along with its education policies that prioritize creative thinking, support scientific production in this area (National Science Board, 2022; Florida, 2004). Furthermore, the dominance of English in academic publishing contributes to the higher visibility and citation rates of U.S.-based studies in the international scholarly community., while k Key journals, such as the *Creativity Research Journal* and *Thinking Skills and Creativity*, have emerged as pivotal publication outlets. In terms of citation impact, we found that authors such as Paulus P.B. have made significant contributions with high publication output, while others like Nijstad B.A. and Stroebe W. are highly cited, reflecting their strong influence on the field. An examination of the co-citation network highlights foundational works such as "How the Group Affects the Mind: A Cognitive Model of Idea Generation in Groups," published by Nijstad and Stroebe (2006) in the *Pers Soc Psychol Rev. journal*, which has garnered 359 citations and is considered highly influential. Our cluster analysis of co-citations further uncovers the research hotspots and emerging trends in the brainstorming literature, with academic performance and creativity identified as key focal areas that warrant close attention for future research. These insights provide us with a nuanced understanding of the intellectual structure and evolution of the brainstorming research landscape.

Strengths and Limitations

This study represents the first large-scale data analysis of research papers related to the brainstorming technique, utilizing the Web of Science (WoS) database. Our findings not only provide a comprehensive visual analysis of publications on the brainstorming technique but also enable co-citation analysis, which captures the foundational research and emerging trends within this field. This analysis serves as a valuable reference for researchers seeking a thorough understanding of the current landscape of brainstorming technique research. While this study's use of bibliometric methods provides

objectivity, it is limited by the exclusive reliance on WoS, potentially excluding significant contributions from non-English language studies or other academic databases. Specifically, we did not conduct an exhaustive literature assessment beyond the WoS; databases such as Scopus, ProQuest, WoK, Medline, Lens.org, and PubMed were not included in our review. For the analysis, we employed the R programming package; however, alternative software options such as VOSviewer and CiteSpace could also facilitate similar analyses. In our investigation, we specifically focused on peer-reviewed articles, thereby excluding other forms of literature. Our analysis concentrated on publications from the years 1981 to 2022, with a deliberate emphasis on the field of education. Future research could explore different temporal frameworks and impose varied limitations within this domain.

Recommendations

In order to disseminate this technique, it is recommended to introduce it through in-service training for its detailed examination, fulfillment of requirements, and implementation in the classroom. This would include classroom practices and the broadening of techniques, as well as collecting feedback from stakeholders. Additionally, the time frame for the study can vary. Keywords other than academic achievement and creativity can also be explored and compared with our study. As a result of the thematic analysis conducted, future topics to be studied include technology, electronic brainstorming, skills especially creative and critical thinking, programs, communication, and imagination. Based on this, it is recommended to integrate technology into the brainstorming technique, activate higher-order thinking skills, ensure its applicability in programs, and investigate how these methods can be used and evaluated in online environments with the spread of digital platforms. More studies may be needed to understand how student profiles and demographic characteristics affect group interaction dynamics. Further research can explore how this technique impacts students' creativity and how this process contributes to innovation processes. Studies on its use at different educational levels or in different disciplines and its effectiveness can also be conducted. Consequently, mixed-method research can highlight whether the brainstorming technique is effective. These recommendations can help researchers develop new study areas or methodologies to fill gaps in education.

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