Brain, Digital, & Learning

pISSN : 2384-2474
eISSN : 2586-7490

RESEARCH ARTICLE

Bibliometric and Clustering Keywords Network Analysis of Scientist Creativity Research

Rahmi Qurota Aini[1] · Yustika Sya'bandari[2] · Ai Nurlaelasari Rusmana[2] · Minsu Ha[2*]
[1]Middle Tennessee State University
[2]Kangwon National University

과학자 창의성 연구에 관한 서지학 및 클러스터링 키워드 네트워크 분석

Rahmi Qurota Aini[1] · Yustika Sya'bandari[2] · Ai Nurlaelasari Rusmana[2] · 하민수[2*]
[1]Middle Tennessee State University · [2]강원대학교

[*]Corresponding Author: msha@kangwon.ac.kr

ABSTRACT

Scientific thought and work have been viewed as a creativity product since 1930, and scientist known as a person who conduct creative work according to the four P creative approach. The limited studies about systematic literature scientist creativity promote this research to examine research trends of scientist creativity. This study also identifies future research implications through qualitative systematic review. Through bibliometric and clustering keywords network analysis, this study explores the research trends related to scientist creativity from 2004 to 2020. Metadata from Web of Science Core Collection database collected and bibliometrics analysis was done to identify the most influential research area, country, and the research trend. Furthermore, co-occurrence keywords analysis, clustering network were created using Text Mining 'TM', Network Analysis Visualization 'igraph' packages in R software. Educational and education research was the most researched area while science and technology were the most influential research area. Clustering network were created and growth of each four cluster topic includes 1) Creativity Research, 2) Educational and Innovation, 3) Art and Creative Process, 4) History and Philosophy of Science were discussed over the time. The first cluster covers creativity research within and between individuals. The second cluster covers the connection between education and innovation where researchers promote creativity in the education sphere leading to innovative products. The third cluster covers arts as the significant domain of the creative field. The fourth cluster covers the history and Philosophy of Science.

Key words: Scientist, creativity, network analysis, research trend

Check for updates

OPEN ACCESS

Brain, Digital, & Learning
2021, Vol. 11, No. 4, 563-576.
https://doi.org/10.31216/BDL.20210036

Received: October 21, 2021
Revised: December 13, 2021
Accepted: December 16, 2021

Introduction

Creativity is an important aspect in all disciplines, particularly in the scientific field, it is a necessary competence for scientists (Tang & Kaufman, 2017). According to Simon (2004), a science researcher's success is often defined by the number of publications which is a result of creative output. Although creativity can be applied across all disciplines, only a few scholars from specific domains (For example, engineering field) conduct studies in the context of creativity (Plucker, 2017). However, there has been a growing interest in studies on creativity in science since the 1980s (Tang & Kaufman, 2017). In recent years, several research studies focusing on creativity have been conducted. A recent study by Long and colleague (Long et al., 2014) analyzed productivity and performance of creativity research studies between 1956 and 2012, and reported a significant increase in creativity research, with four journals published between 1990 and 2010. However, the number of citations for the research papers published during this period was low, indicating a difference in research impact between the early and later period (1990-2010). Previous studies analyzing creativity research trends also conducted by Feist and Runco in the period of 1968-1989 (Feist & Runco, 1993); Beghetto, Plucker, and MaKinster in the period of 1968-1989 (2001), Nemeth and Goncalo in 1981-1990 (2005), and Plucker and colleagues in the period of 1998 to 2002 (2004). The earliest study on creativity research was conducted by Zhang et al. (2015) between 1992 and 2011. However, the study was faced with some limitations including limited time, and inadequate electronic databases, therefore a limited range of journals related to creativity. To address the shortcomings in the previous studies, Plucker and colleagues proposed reports to be included for in a creative research which are, 1) a definition of creativity used, avoiding the rigid definition of variable outcomes of creativity as creativity measure, 2) address the context and subject of creativity being used (Plucker et al., 2004) So far, there are no comprehensive studies on scientist creativity trends, limiting further research on science creativity in individual disciplines.

This study aims to examine the thematic trends of research about scientist creativity, through a systematic analysis of the keywords used in academic publications from 2004 to 2020, in an analysis of 990 articles. The following questions guided the analysis of this study:

RQ 1. How was the trend on scientist creativity research between 2004 and 2019?

RQ 2. How was the impact on scientist creativity research across areas?

RQ3 3. What were the thematic clusters of keywords used on the research of scientist creativity?

The Concept of Creativity

The word creativity has been in existence since 1930, by Patrick to describe the creative thought of poets, artists, and scientific thought (1935, 1937, 1938). The study of creativity started to intensify in 1950 and continued to grow throughout the decade, with Guilford being a great contributor who proposed the classification of creativity as an empirical phenomenon (Kaufman, 2016). According to Baer & Kaufman (2006), Guilford's contributions were adequately presented in articles that were published between 1994 and 2003. Guilford's model of creativity consists of four components which include fluency, flexibility, originality, and elaboration which refers to divergent thinking. Furthermore, Sternberg started his study in 1984 and focused on the triarchic theory of intelligence, which further brought forth more understanding of the concept of creativity using three models; intelligence, cognitive style, and personality, or motivation (Dai & Sternberg, 2004; Sternberg & Sternberg 1998; Sternberg et al., 2001). Despite these converging views, many recent researchers nowadays argue that creativity is more than divergent thinking (Kaufman, 2016; Runco, 2008; Runco & Jaeger, 2012). In 2004, Plucker et al. (2004), also stated in subsequent creativity study that researchers should define creativity, discuss how the words they use to describe creativity are used, discuss how they are different from other provided definitions, and answer the question on how this creativity occurs and in which context. They also examined and analyzed journals related to creativity published between 1998 and 2002. According to the result, the concepts of creativity that were observed is the explicit definition of uniqueness and usefulness. This means that many scholars require creativity to have originality and effectiveness, where effectiveness also means usefulness and appropriateness (Runco & Jaeger, 2012; Smith & Smith, 2017).

The creative research discussion should also show where the creativity definition takes place. The four P approach which consists of product, process, person, and press (or environment) are the approaches that help to understand major creativity theories (Kaufman, 2016). The analysis of creativity aspects using the four P is also used to classify creativity measurement (Haase et al., 2018). For instance, creative products as the most studied and measured aspect focused on creative contributions such as painting, designing, and scientific experiments which are usually tangible objects (Kaufman, 2016). The creative products can be measured using instruments such as Urban's Test of Creative Thinking Drawing Production (Haase et al., 2018) or Amabile's college test (1982) and measured under the expert agreement. The approach to the creative process typically focuses on the orientation of the cognitive component, the idea of how people think creatively (Blair & Mumford, 2007; Kaufman, 2016; Mumford et al., 1991; Rothenberg, 1988; Wallas, 1926). Sternberg and Lubart (1966) proposed a list of variables that represent the creative person that included, intelligence, knowledge, personality, environment, motivation, and thinking styles. Amabile (1982, 2016) also proposed three variables needed for creativity which include dominant-relevant skills, creativity-relevant skills, and motivation toward the task. Lastly, creative press or creative environment which usually refers to how an environment influences group creativity (Kaufman, 2016).

Bibliographic and Keywords Network analysis

Bibliometric analysis of published work is a method used to evaluate scientific research trends and to show the disposition of scientific disciplines (Zhang et al., 2016) Bibliometric analysis has been used to examine historical research development in specific fields and is significant in discovering trending topics within the fields. Further, bibliometric can be used to track the performance of scientific research publications both quantitatively and qualitatively by decision-makers (Ellegaard & Wallin, 2015). For instance, many scholars have used bibliometric methods such as in the medical field (Iftikhar et al., 2019), engineering, and management (Wang et al., 2020) creativity in the field of business and economy (Castillo-Vergara et al., 2018). Databases from web-based citation indexing such as Web of Science (WoS), Scopus, Google Scholar increase the scope of analysis because they list various sets of information regarding published research work such as the name of the author, keyword used, research area, cited reference. Specifically, Web of Science provides the journal with Social Science Citation Index (SSCI), Arts and Humanities Citation Index (A&HCI), Science Citation Index Expanded (ECI-EXPANDED), and Emerging Sources Citation Index (ESCI) (Clarivate Analytics, 2020). Furthermore, citation analysis can be used as a convenient way of investigating the impacts of research and individual research (Frandsen et al., 2005; Waltman et al., 2012; Weingart, 2005).

Network analysis (NA) of keywords co-occurrence has been gaining importance in investigating summary information in a research field. It is performed based on bibliometric research database; some also uses authors' relation, titles or abstracts of papers, and cited relations (Van Eck & Waltman, 2014) Network analysis using co-occurrence keywords shows existing relationships between keywords and reveal structure and development in the research field. Further, co-occurrence keyword network analysis provides information such as the distribution of keywords, degree distribution, clustering (community detection within selected keywords), and analysis to gain understanding about them (Lozano et al., 2019). To understand the knowledge structure of the field, the clustering algorithm is used (Lozano et al., 2019). Kleinberg's Hub Centrality can be used to evaluate connectivity (Kleinberg, 1999; Bakillah et al., 2015). Previous studies used fast-greedy optimization of the popularity (FGM) clustering algorithm to classify the data (Gardner, 1993; Luo et al., 2015). In a nutshell, interpreting co-occurrence within keywords can be insightful in revealing relations in the complex network (Lozano et al., 2019).

Methods

Data Collection

A total of 990 publications for the period between 2004 and 2020 were collected from the Web of Science Core Collection, an online academic search database. Data were extracted on the 26th of July 2020 using search query design; 1) Search Topic for 'scientist' AND 'creativity' NOT 'creative', and 2) Search Topic for 'scientist' AND 'creative' NOT 'creativity'. The search yielded a total of 335 and 655 publications from both criteria receptively. The data was exported and merged into an excel sheet.

Keywords of creative and creativity were chosen based on the similarity of meaning; where creative scientists intended to search 'a person who is creative' or 'product of creativity by scientist', while scientist creativity intended to search 'the process or production of creative work'. Furthermore, scientist creativity terms will be used in the following study. Using search query based on 'Topic' was chosen to find records of keyword scientist creativity in the Title, Abstract, Author Keywords, and Keywords Plus.

Data Analysis

From the search query on Web of Science Core Collection database, publication years, title, keywords (offered by author), the sum of total citation, research area, and the country showed up as metadata (Fig. 1.1). For authenticity, author keywords were chosen for keyword analysis. Metadata were imported to RStudio software version 3.5.3 (Fig. 1.2). Data preprocessing was done using Text mining 'TM' package by transforming the keywords to lowercase, removing unnecessary words ('and', 'the', 'for') and stop words (commonly words used in English), removing punctuation, and replacing similar meaning words (Fig. 1.3). The term frequency (tf) was calculated to determine the number of times words that occurred in a document and the term-document matrix (tdm) was created for further analysis (Fig. 1.4). Only the words that appeared (frequency) more than 14 times were selected for the network analysis. Furthermore, the undirected network with zero diagonal of the matrix in the calculation was generated, and the quantity of centrality was measured using iGraph package. Network are created based on the extracted co-occurrences keywords (Fig. 1.5). Vertices (or nodes) indicate individual words unit while edges indicate the connection of vertices. The sizes of the verticles in the network plot are set based on hub scores (Kleinberg's hub centrality scores), 14 times from normal size. Cluster analysis of keyword-based networks was done to identify group clusters or density of the subgraph by directly optimizing a modularity score to find dense subgraphs (Fig. 1.6). The publication trend in each cluster keywords was computed. Bibliometric analysis results from the metadata were also used to find the general view about scientist creativity from top articles, research areas, and countries.

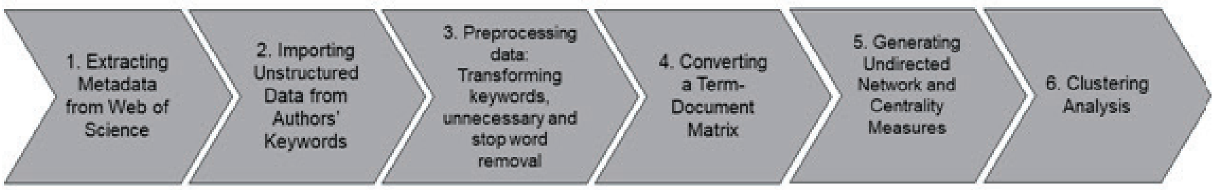

Fig. 1. Clustering keyword-based network analysis

Results

RQ 1. The Research Trends about Scientist Creativity

Bibliometric Analysis

During the period between 2004 and 2019, the cumulative number of published articles on the scientist creativity increased gradually with its peak in 2017 (138 publications). The number of publications citations also increased substantially over the period with the highest increase being experienced between 2016 and 2017. This citation analysis can be used as an indicator of the impact of publication traditionally, and the developing research trend.

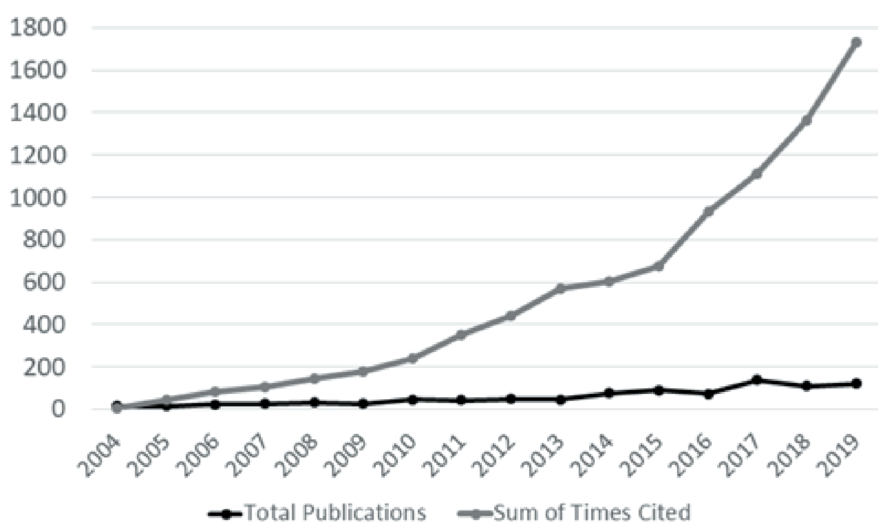

Fig. 2. Total number of publication and number of citations between 2004 and 2019

A total 110 publications were recorded in the education, and educational research category (9.03%), which fell in the social sciences category. Arts and humanities and other related topics constituted 5.57% while science technology topics were 5.25%. Table 1 shows the 10 most frequently researched areas on the topic of *scientist creativity* between 2004 and 2020. Among the publications, which covered 76 different countries, most of the publications originated from the USA (26.78%) followed by Russia (14.75%), England (7.02%), and Germany (5.97%).

Table 1. Top 10 most frequently researched area

No	Web of Science research area	Records	Percentage
1	Education Educational Research	110	9.03%
2	Arts Humanities Other Topics	70	5.75%
3	Science Technology Other Topics	64	5.25%
4	Psychology	48	3.94%
5	Environmental Sciences Ecology	47	3.86%
6	Business Economics	45	3.69%
7	Chemistry	44	3.61%
8	History	42	3.45%
9	History Philosophy of Science	39	3.20%
10	Engineering	38	3.12%

The total number of citations recorded from the Web of Science Core Collection listing the number of publications cited in the database, showing the reference of the research and impact of publications. Table 2 shows the most cited publications in the scientist's creativity topic, each column showing the top 5 most researched areas from 2007 to 2020. According to the data, the publication with the greatest impact was also found in the area of science and technology followed by environmental science and ecology.

RQ 2. The Impact on Scientist Creativity Research across Areas

According to the records, the most researched area is education. Our results showed a high number of creativity theory frameworks used in analyzing learners, and creativity researchers who have contributed to the study of constructivism during learning and teaching (Plucker et al., 2004). Therefore, it is not surprising that creativity study is spread in the cognitive psychology and education areas (Kaufman, 2016), For instance, creativity regarding intellectual ability (Hofstee et al., 1992; Park et al., 2007), personality (Baer & Kuafman, 2006; Feist, 1998; Hofstee et al., 1992), and cognitive development (Patrick, 1938). Additionally, the number of science creativity topics in the educational area shows consistent interest in the research on creativity study as a creative process. For example, the selected articles (Table 2) shows educational intervention studies for students studying nature of science using metacognitive prompts embedded within experimental students' groups which use aspects of nature of science that apply scientist creativity to explain event using evidence (Peters & Kitsantas, 2010). Further, Art and humanities, and science - technology - research areas showed interest in the creative process and creativity products from a scientist. Based on our analysis, it is evident that creative innovations made by scientists have a higher frequency within research areas as well as a greater impact, and the nature of the research is replicable. Selected articles from the psychology area discussed changes within psychological science standards on scientific claim impacting creativity and discussed scientists' rate of scientific progress (Vazire, 2018). Articles selected from the environmental sciences and Ecology area discussed the development of ecology that was introduced by a scientist in North America which requires a creative insight.

Table 2. Most cited in web of science core collection

No	Times cited*	Research area	Publication Title	Publish year
1	38	Education & Educational Research	The Effect of Nature of Science Metacognitive Prompts on Science Students' Content and Nature of Science Knowledge, Metacognition, and Self-Regulatory Efficacy	2010
2	27	Arts & Humanities - Other Topics	Gut Buddies Multispecies Studies and the Microbiome	2016
3	207	Science & Technology - Other Topics	Inspirations from biological, optics for advanced phtonic systems	2005
4	41	Psychology	Implications of the Credibility Revolution for Productivity, Creativity, and Progress	2018
5	135	Environmental Sciences & Ecology	Landscape ecology in North America: Past, present, and future	2005

RQ 3. Clustering Network Analysis

The result of keyword network analysis shows 64 words extracted which is appeared more than 14 times (frequency). As a result, 'Science', 'Research', and 'Education' keywords were the most frequent words with high connection (degree) with other keywords and high connectivity between pairs of edge weight for each vertex (strength). These keywords also become the central of vertex according to the betweenness centrality. Following that, keywords 'Scientific', 'Creativity', and 'Art' are the most frequent keywords in overall. Furthermore, keywords 'Technology', 'System', and 'Training' also lies as important keywords because it connecting many vertex in the nodes with high betweenness centrality. The visualization of network is presented in Fig. 3 and most frequently used keywords and its centrality scores are presented in Table 3.

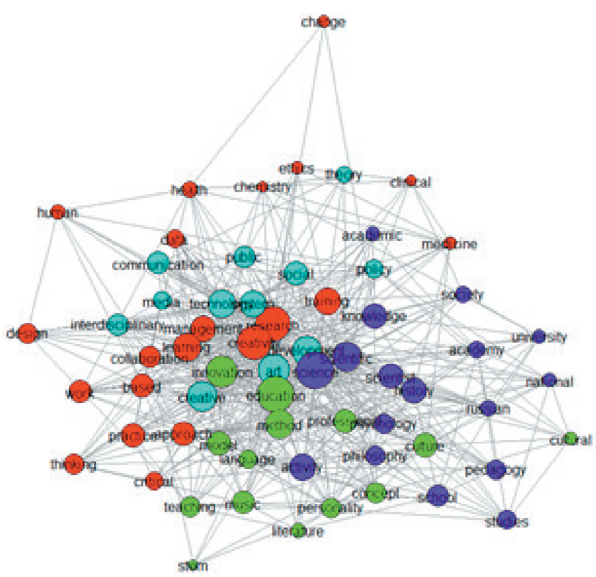

Fig. 3. Network of creative scientist keywords study

Table 3. Centrality measure of network

No	Cluster	Keywords	Freq	Strength	Centrality				No	Cluster	Keywords	Freq	Strength	Centrality			
					Degree	closeness	betweenness	hubs						Degree	closeness	betweenness	hubs
1	Cluster 1: Creativity research	research	103	295	47	0.0038	101.68	0.69	33		cultural	15	27	8	0.0030	3.29	0.04
2		creativity	68	155	35	0.0040	131.43	0.41	34		stem	15	19	5	0.0029	2.47	0.06
3		learning	37	109	27	0.0039	38.61	0.24	35		teaching	15	62	14	0.0030	5.20	0.13
4		collaboration	31	69	16	0.0033	12.91	0.24	36	Cluster 3: Art and creative process	art	66	208	32	0.0037	40.20	0.57
5		training	28	84	23	0.0041	70.46	0.21	37		creative	41	118	27	0.0035	17.13	0.30
6		management	27	92	22	0.0038	28.00	0.27	38		system	41	114	27	0.0038	71.13	0.30
7		based	26	108	23	0.0034	16.28	0.27	39		development	39	111	29	0.0037	37.36	0.26
8		medicine	22	31	11	0.0037	59.80	0.07	40		social	38	82	19	0.0036	28.04	0.22
9		approach	21	65	19	0.0036	20.65	0.14	41		technology	35	114	25	0.0038	74.23	0.34
10		health	20	38	11	0.0032	20.92	0.08	42		public	23	84	16	0.0034	7.75	0.23
11		thinking	19	38	12	0.0033	15.60	0.08	43		theory	21	24	6	0.0028	0.50	0.08
12		work	18	44	12	0.0033	19.54	0.12	44		policy	19	58	15	0.0035	35.62	0.16
13		data	17	32	12	0.0036	14.27	0.11	45		communication	18	47	12	0.0031	5.25	0.14
14		ethics	17	27	7	0.0032	9.18	0.07	46		media	18	64	15	0.0035	20.50	0.21
15		practice	17	49	17	0.0038	39.48	0.13	47		interdisciplinary	15	55	15	0.0036	8.87	0.19
16		clinical	16	29	7	0.0027	2.51	0.08	48		science	170	442	52	0.0033	31.36	1.00
17		change	15	6	3	0.0029	6.93	0.01	49	Cluster 4: History and philosophy of science	scientific	75	194	34	0.0035	36.71	0.56
18		chemistry	15	29	8	0.0034	17.69	0.06	50		history	58	143	25	0.0033	14.05	0.39
19		critical	15	39	11	0.0033	1.53	0.11	51		knowledge	36	89	22	0.0035	47.95	0.24
20		design	15	26	9	0.0032	17.52	0.08	52		scientist	28	73	20	0.0037	38.98	0.23
21		human	15	21	9	0.0035	30.03	0.04	53		society	24	40	11	0.0032	20.47	0.13
22	Cluster 2: Education and Innovation	education	98	254	51	0.0041	162.18	0.57	54		philosophy	22	50	12	0.0032	5.50	0.19
23		innovation	47	122	28	0.0036	52.28	0.29	55		psychology	22	77	18	0.0035	14.38	0.22
24		culture	40	78	21	0.0034	48.00	0.13	56		school	22	48	13	0.0031	11.60	0.12
25		method	36	141	32	0.0037	56.61	0.34	57		university	21	38	9	0.0030	7.40	0.11
26		literature	21	60	9	0.0028	1.12	0.15	58		academic	20	32	10	0.0034	4.18	0.11
27		model	21	66	20	0.0038	31.94	0.16	59		russian	20	54	15	0.0035	33.09	0.16
28		professional	21	70	22	0.0039	53.48	0.14	60		activity	19	73	22	0.0036	44.81	0.17
29		music	20	50	16	0.0037	45.60	0.11	61		studies	19	30	11	0.0035	23.80	0.07
30		language	18	62	16	0.0033	8.44	0.11	62		academy	16	56	13	0.0034	24.16	0.21
31		personality	18	61	17	0.0036	26.05	0.10	63		pedagogy	16	24	9	0.0034	34.49	0.08
32		concept	16	43	15	0.0037	64.21	0.12	64		national	15	33	11	0.0035	27.99	0.10

The clustering network analysis of related keywords based on modularity score was done and yielded four clusters. ‘Research’, ‘Creativity’, ‘Learning’, ‘Collaboration’, and ‘Training’ were the five most frequent keywords in cluster one, which was about Creativity Research. The second cluster was about innovation in education, the most frequent keywords were, ‘Culture’, ‘Method’, ‘Literature’ after ‘Education’ and ‘innovation’ as the most frequent. The third cluster was about arts and creative process by the appearance of keywords ‘Art’, ‘Creative’, ‘System’, and ‘Development’. The fourth cluster was about history and philosophy of science (HPS), frequent keywords included ‘Science’, ‘Scientific’, ‘History’, and ‘Philosophy’.

Fig. 4 shows the research trend from the most frequent keywords in each cluster related to scientist creativity from 2004 to 2020. Overall, the rapid increase between 2012 and 2014 in each cluster with cluster 4 taking lead during the entire period. According to the data, keywords ‘Science’ ‘Scientific’ and ‘History’ contributes majorly to the rapid increase in between 2014 and 2017. Although the overall pattern was similar, the trend shows that scientist creativity is more extensively researched in the history of science field it shows that the trend of research about history of science in the topic of scientist creativity higher than in the other fields.

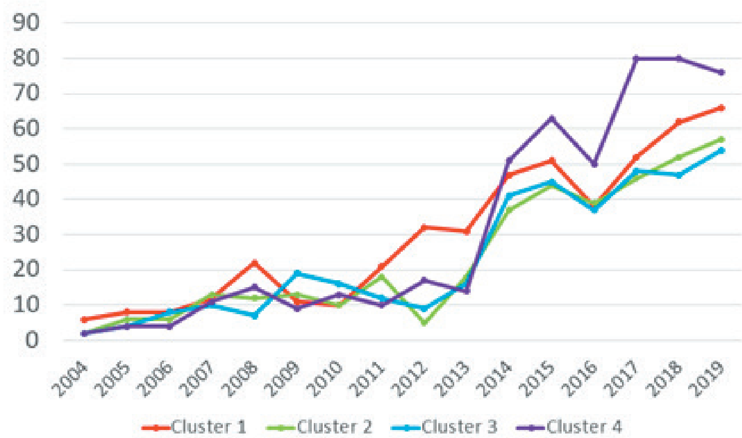

Fig. 4. The trend of keywords in Each Group

As shown in Fig. 4, the following five idea cluster about scientist creativity research:

Cluster 1: Creativity Research

‘Research,’ ‘Creativity,’ ‘Learning’ and ‘Collaboration’ had the highest number of nodes (frequency and degree) in this cluster. These nodes also represent the most important keywords of network within this cluster. Research about creativity is often associated with learning and training as cognitive progression within an individual and collaboration as a cognitive progression between individuals. Therefore, this cluster is linked with the creative environment such as collaboration and management. However, this does not imply that creativity exclusively applies to higher education, it is also applied in other fields such as health. Keywords ‘Medicine’ in this cluster have higher number of betweenness centrality which implies this node is crucial for the network flow. For instance, one of the publications containing these keywords was an intervention study for biomedical science students to develop creativity learning (Brooks et al., 2014). In this case, a research gap was found regarding the role of creativity in reflective ability and critical thinking for biomedical students.

Cluster 2: Education and Innovation

The perception that creativity is a necessary skill in the 21st century encourages educational practitioners to train a creative workforce. Education can be a systematic tool for promoting creative thinking leading to innovative products. For instance, OECD's Programme for International Student Assessment (PISA) 2021 will include creative thinking in their assessment because it is now believed that creative thinking leads to innovation. A study by Gali and colleagues (2019) showed conditions and factors that affect linguistic students' abilities for creative achievement. Another study investigated program effects that led female students to choose a STEM career (Bamberger, 2014). Apart from being a tangible competence, creative thinking is also an essential learning skill that can improve students' abilities, metacognitive capacity, problem-solving skills, and future success (OCED, 2021). Therefore, this is an important research area and scholars should be encouraged to learn about creativity in the education field. Based on this analysis, we can conclude that creative thinking has a major role in education, and education also plays a major role in creative thinking.

Cluster 3: Art and creative process

Creativity is domain-specific, as demonstrated by its performance assessment of creativity (Patrick, 1938). For a long time, arts have been significant domains of creativity and novices may perceive creativity to only revolve around arts. In this cluster network analysis showed that arts connect with the creative system, including 'development', 'social', 'technology' and 'media', with strong density connections each other from the network. The example of this cluster analysis reveals an opportunity in building an art system as interdisciplinary work that can be explored by scientists (DiPaola, 2016).

Cluster 4: History and Philosophy of Science

Philosophy of science concerns with the method and implication of science and is never detached from the way scientists think and innovate. The research about scientist creativity in philosophy and history areas clearly shows the contributions of creative process for scientists. According to Licona and Kelly (2018), the history and philosophy of science are valuable and their impact on creative thinking. The studies on scientific practice are expected to produce knowledge on how science is conducted, proposed, communicated, and evaluated. Therefore, this cluster showed the network on science as the empirical study that could be seen from an educational and historical perspective with its issues with pedagogy and society.

Conclusion

This study presented a bibliometric and clustering keyword network analysis on scientist creativity from 2004 to 2020. Using a total of 990 publications from two search queries in the Web of Science, it was noted that the number of publications about scientist creativity topic has been increasing gradually over the years. The number of times this topic has been cited has also increased exponentially, with the highest number of citations in 2016 and 2018.

Most of creativity theories and frameworks were applied in the education and psychology research areas because they follow the famed history of creativity study, which defines creativity as divergent thinking. However, this study found that the science and technology research area was the most impactful field as demonstrated by the number of citations. The present study, classified scientist creativity into four major clusters. The first cluster covers creativity research within and between individuals. The second cluster covers the connection between education and innovation where researchers promote creativity in the education sphere leading to innovative products. The third cluster covers arts as the significant domain of the creative field. The fourth cluster covers the history and Philosophy of Science.

Significant and Limitation

Bibliometric and clustering keywords network analysis offers the possibility to shows show various themes related to research topics and the development of trends related to scientist creativity. In addition, the result also provides recommendations for future work and the visualizing trends in the field of science from published articles. According to the result, this study also detected the biggest impact on the educational research field, which can be significant to relevant practitioners and researchers. An understanding of interdisciplinary study among various disciplines provided in this study perhaps can help strengthen the fundamental concept of scientist creativity.

The process to identify thematic trends used the words as the unit of analysis. There are several limitations to this analysis. First, researchers need to find and correct related words manually. For instance, the words "collaborations" should be replaced with "collaboration" so that the analysis could account for these words as the same term. This method was done iteratively by calculating every term frequency (tf) of words used, sorting words, and replacing words, and finally creating a term-document matrix (tdm). Second, this analysis used all the words regardless of part of speech. Therefore, every keyword would be detected equally and threaten for content analysis. Lastly, the result of this study would not grasp the definition of scientist creativity, but only identify the relational structure between keywords from research related to scientist creativity.

Acknowledgments

This study was funded by the National Research Foundation of Korea (NRF, NRF-2020R1C1C1006167).

References

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. Journal of Personality and Social Psychology, 43, 997.

Amabile, T. M., & Pratt, M. G. (2016). The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. Research in Organizational Behavior, 36, 157-183.

Baer, J., & Kaufman, J. C. (2006). Creativity Research in English-Speaking Countries. Cambridge University Press.

Bakillah, M., Li, R. Y., & Liang, S. H. (2015). Geo-located community detection in Twitter with enhanced fast-greedy optimization of modularity: the case study of typhoon Haiyan. International Journal of Geographical Information Science, 29, 258-279.
Bamberger, Y. M. (2014). Encouraging girls into science and technology with feminine role model: Does this work? Journal of Science Education and Technology, 23, 549-561.
Beghetto, R. A., Plucker, J. A., & MaKinster, J. G. (2001). Who studies creativity and how do we know? Creativity Research Journal, 13, 351-357.
Blair, C. S., & Mumford, M. D. (2007). Errors in idea evaluation: Preference for the unoriginal? The Journal of Creative Behavior, 41, 197-222.
Brooks, R., Kay, J., Smith, S., & Martin, J. (2014). Practitioner capability. Higher Education, Skills and Work-based Learning, 10, 687-692
Castillo-Vergara, M., Alvarez-Marin, A., & Placencio-Hidalgo, D. (2018). A bibliometric analysis of creativity in the field of business economics. Journal of Business Research, 85, 1-9.
Clarivate Analytics. (2020). Web of Science Core Collection. Retrieved from www.webofknowledge.com
Dai, D. Y., & Sternberg, R. J. (Eds.). (2004). Motivation, Emotion, and Cognition: Integrative Perspectives on Intellectual Functioning and Development. Routledge.
DiPaola, S. (2009). Exploring a parameterised portrait painting space. International Journal of Arts and Technology, 2, 82-93.
Ellegaard, O., & Wallin, J. A. (2015). The bibliometric analysis of scholarly production: How great is the impact? Scientometrics, 105, 1809-1831.
Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. Personality and Social Psychology Review, 2, 290-309.
Feist, G. J., & Runco, M. A. (1993). Trends in the creativity literature: An analysis of research in the Journal of Creative Behavior (1967–1989). Creativity Research Journal, 6, 271-283.
Frandsen, T. F., & Rousseau, R. (2005). Article impact calculated over arbitrary periods. Journal of the American Society for Information Science and Technology, 56, 58-62.
Gali, G. F., Fakhrutdinova, A. V., Dulmukhametova, G. F., Gilyazova, K. R., & Gali, A. I. (2019). Methodical features of foreign language teaching to linguistically gifted students of non-linguistic specialties: Foreign experience. International Review, 2019, 106-112.
Gardner, H. (2011). Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Ghandi. Civitas books.
Haase, J., Hoff, E. V., Hanel, P. H., & Innes-Ker, Å. (2018). A meta-analysis of the relation between creative self-efficacy and different creativity measurements. Creativity Research Journal, 30, 1-16.
Hofstee, W. K., De Raad, B., & Goldberg, L. R. (1992). Integration of the big five and circumplex approaches to trait structure. Journal of Personality and Social Psychology, 63, 146.
Iftikhar, P. M., Ali, F., Faisaluddin, M., Khayyat, A., De Sa, M. D. G., & Rao, T. (2019). A bibliometric analysis of the top 30 most-cited articles in gestational diabetes mellitus literature (1946-2019). Cureus, 11, e4131.
Kaufman, J. C. (2016). Creativity 101. Springer publishing company.
Kelly, G. J., & Licona, P. (2018). Epistemic practices and science education. In M. Matthews (Ed.), History, Philosophy and Science Teaching (pp. 139-165). Springer, Cham.
Kleinberg, J. M. (1999). Hubs, authorities, and communities. ACM Computing Surveys (CSUR), 31, 5-es.
Long, H., Plucker, J. A., Yu, Q., Ding, Y., & Kaufman, J. C. (2014). Research productivity and performance of journals in the creativity sciences: A bibliometric analysis. Creativity Research Journal, 26, 353-360.
Lozano, S., Calzada-Infante, L., Adenso-Díaz, B., & García, S. (2019). Complex network analysis of keywords co-occurrence in the recent efficiency analysis literature. Scientometrics, 120, 609-629.

Luo, H., Ye, H., Ng, H. W., Shi, L., Tong, W., Mattes, W., ... Hong, H. (2015, December). Understanding and predicting binding between human leukocyte antigens (HLAs) and peptides by network analysis. In BMC Bioinformatics (Vol. 16, No. 13, pp. 1-9). BioMed Central.

Mumford, M. D., Mobley, M. I., Reiter - Palmon, R., Uhlman, C. E., & Doares, L. M. (1991). Process analytic models of creative capacities. Creativity Research Journal, 4, 91-122.

Nemeth, C. J., & Goncalo, J. A. (2005). Creative collaborations from afar: The benefits of independent authors. Creativity Research Journal, 17, 1-8.

OCED, PISA (2021). Creative Thinking Framework, 2019. Retrieved from https://www.oecd.org/pisa/publications

Park, G., Lubinski, D., & Benbow, C. P. (2007). Contrasting intellectual patterns predict creativity in the arts and sciences: Tracking intellectually precocious youth over 25 years. Psychological Science, 18, 948-952.

Patrick, C. (1935). Creative Thought in Poets (No. 178). Columbia University.

Patrick, C. (1937). Creative thought in artists. The Journal of Psychology, 4, 35-73.

Patrick, C. (1938). Scientific thought. The Journal of Psychology, 5, 55-83.

Peters, E., & Kitsantas, A. (2010). The effect of nature of science metacognitive prompts on science students' content and nature of science knowledge, metacognition, and self - regulatory efficacy. School Science and Mathematics, 110, 382-396.

Plucker, J. A. (2017). Toward a science of creativity: Considerable progress but much work to be done. The Journal of Creative Behavior, 51, 301-304.

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. Educational Psychologist, 39, 83-96.

Rothenberg, A. (1988). Creativity and the homospatial process: Experimental studies. Psychiatric Clinics of North America, 11, 443-459.

Runco, M. A. (2008). Commentary: Divergent thinking is not synonymous with creativity. Creativity, and the Arts, 2, 93-96.

Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. Creativity Research Journal, 24, 92-96.

Simonton, D. K. (2004). Creativity in Science: Chance, Logic, Genius, and Zeitgeist. Cambridge University Press.

Smith, J. K., & Smith, L. F. (2017). The 1.5 criterion model of creativity: Where less is more, more or less. The Journal of Creative Behavior, 51, 281-284.

STERNBERG, R. J. E., & Sternberg, R. J. P. (1988). The Nature of Creativity: Contemporary Psychological Perspectives. CUP Archive.

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. American Psychologist, 51, 677.

Sternberg, R. J., Grigorenko, E. L., & Bundy, D. A. (2001). The predictive value of IQ. Merrill-Palmer Quarterly, 47, 1-41.

Tang, C., & Kaufman, J. C. (2017). Personal characteristics that distinguish creative scientists from less creative scientists. The Journal of Creative Behavior, 51, 204-215.

Urban, K. K. (2005). Assessing Creativity: The Test for Creative Thinking-Drawing Production (TCT-DP). International Education Journal, 6, 272-280.

Van Eck, N. J., & Waltman, L. (2014). Visualizing bibliometric networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds), Measuring Scholarly Impact (pp. 285-320). Springer, Cham.

Vazire, S. (2018). Implications of the credibility revolution for productivity, creativity, and progress. Perspectives on Psychological Science, 13, 411-417.
Wallas, G. (1926). The Art of Thought. New York: Harcourt
Waltman, L., Calero‐Medina, C., Kosten, J., Noyons, E. C., Tijssen, R. J., van Eck, N. J., ... Wouters, P. (2012). The Leiden Ranking 2011/2012: Data collection, indicators, and interpretation. Journal of the American Society for Information Science and Technology, 63, 2419-2432.
Wang, T., Chan, A. P., He, Q., & Xu, J. (2020). Identifying the gaps in construction megaproject management research: A bibliographic analysis. International Journal of Construction Management, 1-12.
Weingart, P. (2005). Impact of bibliometrics upon the science system: Inadvertent consequences? Scientometrics, 62, 117-131.
Zhang, J., Yu, Q., Zheng, F., Long, C., Lu, Z., & Duan, Z. (2016). Comparing keywords plus of WOS and author keywords: A case study of patient adherence research. Journal of the Association for Information Science and Technology, 67, 967-972.
Zhang, W., Zhang, Q., Yu, B., & Zhao, L. (2015). Knowledge map of creativity research based on keywords network and co-word analysis, 1992–2011. Quality & Quantity, 49, 1023-1038.

Authors Information

Aini, Rahmi Qurota: Middle Tennessee State University, Graduate student, First Author
Sya'bandari, Yustika: Kangwon National University, Graduate student, Co-author
Rusmana, Ai Nurlaelasari: Kangwon National University, Graduate student, Co-author
Ha, Minsu: Kangwon National University, Professor, Corresponding Author