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Original Research

Co-authorship Network of Hot Papers of the Science Citation Index-Expanded in the Web of Science Core Collection

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Abstract

The present study was conducted to draw the co-authorship network of hot papers of science citation index in the Web of Science (WOS) database from 2020 to 2021. This investigation is a descriptive study using a scientometrics approach. This research was conducted using social network analysis indices to visualize the co-authorship networks of hot papers in the science citation index. The structure of the co-authorship network of researchers of hot papers in the field of science consists of 47,045 authors who have contributed to the publication of 3475 hot papers from 2020 to 2021, which indicates the high co-authorship of these authors. Moreover, it was found that among the co-authorship patterns of these researchers, the most significant number of articles during the studied years was related to the five-author collaborations. Moreover, the average Collaboration Coefficient (CC) of the authors of hot papers was higher than 0.80, indicating the authors' strong tendency to produce joint articles. The high collaboration of the authors of hot papers in the science citation index can be one of the reasons for increasing the level of visibility and the potential for using them.

Keywords: Co-Authorship, Hot Papers, Web of Science, WOS, Co-Authorship Networks.

Introduction

The production of scientific information is one of the most important factors in the development of countries. Scientific collaboration between individuals, research organizations, and different countries is increasing with considerable acceleration for science development. Scientific collaboration can be considered a reflection of the activities and approaches of the scientific community; studying and investigating this category can also be effective for the sociology of science (Bagheri & Mohammad Ismaili, 2013). The current era is the era of collaboration and interaction, and consultation is the key element in all fields for progressing and reaching high-quality work. In the realm of scientific research and productivity, substantial

emphasis must be placed on scientific collaborations and knowledge exchange, as they constitute vital and significant measures. In scientific interaction, two or more authors produce a work by thinking together and sharing their knowledge. In many cases, research is complex, requires specialized knowledge, and may require knowledge beyond that of a single person. Moreover, collaboration allows researchers to play the role of an effective companion and complement the knowledge and skills of others (Bagheri & Mohammad Esmaili, 2013).

The number of scientific productions indexed in reliable databases such as the Web of Science Core Collection (WOSCC) is considered one of the important criteria for scientific evaluation and ranking of countries, researchers, institutions, and universities in the world. In some countries, the number of scientific productions in reliable international databases is one of the indices for allocating funds to universities and institutions. (Yousefi, Hemmat, Gilvari & Shahmirzadi, 2012).

A joint article written by two or more authors is proof of collaboration between them. One of the prominent instances of scientific collaboration is co-authorship. In scientific environments and regarding scientific collaboration, co-authorship is the most visible and accessible index used to measure scientific collaboration. Calculating co-authorship in scientific publications is theoretically simple and related to the rate of scientific collaboration (Erfanmenesh and Basirian Jahormi, 2013). According to Cheong and Corbitt (2009), several studies have emphasized the presence of a positive correlation between scientific collaboration and co-authorship; therefore, co-authorship can be considered one of the most tangible and reliable forms of scientific collaboration. The scientific collaboration formed in producing articles, books, etc., is called co-authorship (Soheili, Osareh & Farajpahluo, 2013). Scientific collaborations between researchers and authors in a scientific field form a co-authorship network. In a co-authorship network, the agents or nodes of the network are authors and researchers who have collaborated in writing articles through communication and scientific interaction; therefore, they establish a scientific connection with each other. If two authors participate in writing an article together, they are called scientific collaborators and contribute to the development of a co-authorship network in their scientific field. Social networks are generally groups of people or organizations with common characteristics and interests that are closely related to each other and come together to achieve specific aims. The main feature of social networks is the existence of relationships and interactions between their members. In a co-authorship network, under the title scientific collaboration, researchers collaborate and communicate with each other to produce scientific works and author and write new and joint work such as a book, article, research project, etc. Co-authorship networks take different structures and models based on the type of communication between authors and researchers in a social network. (Bródka, Skibicki, Kazienko & Musial, 2011).

Hariri and Nikzad (2011) believe that science production in the formats of articles, books, reports of research projects, notes, etc., is formed as a result of internetwork co-authorship of authors. Co-authorship network is a type of social network. This network includes a set of nodes and connections; the nodes are the authors, and the connections are the communication lines between them. Each author or actor (node) assigns a special place in the network. The level of collaboration of authors in this network is determined by the number of connections they have. Nowadays, this method is extensively used as a qualitative model to analyze the configuration of networks and the places of and interactions between individuals in the social network.

One of the indices of co-authorship is called the Collaborative Coefficient (CC) or the rate

of collaboration among the authors of the articles; if this value is higher than 5%, it indicates that the collaboration between the authors is at a highly desirable level, and the closer this value is to zero, the weaker the level of collaboration between the authors (Afshar, Abdulmaji & Danesh, 2009).

The rate of scientific collaboration in various fields is different. The global characteristic of basic sciences is an effective factor in international collaborations in their related productions. Moreover, collaboration is necessary for some subject areas, including engineering, which requires materials, tools, laboratory facilities, a high budget, and many researchers to carry out designs and research (Vimala & Reddi, 1996).

Drawing the structure of science and co-authorship networks in different subject areas has also been the focus of researchers in information science for many years. The analysis results of such investigations can be employed as a suitable and practical tool for researchers, authors, and scientists in the relevant scientific fields (Abassi, Aslaninya & Bigloo, 2014). Drawing the co-authorship network is among the scientometric techniques, which makes researchers aware of the status of the conducted research pieces and the connections of the collaborators in that field, and finally illustrates these connections in a graphical form and schematically.

Science is one of the important scientific fields. Science research requires high funds, specialized human resources in various fields, and advanced equipment and devices. Since scientific collaboration is one of the most logical ways to optimize and speed up research, measuring different aspects of this field can effectively direct future research and planning for balanced development in different fields of science (Shekofteh & Hariri, 2014). Being aware of the researcher's scientific collaboration behavior and the patterns of this behavior at different levels makes scientific communication more transparent in a subject area or a country or region and makes decision-making in planning and facilitating scientific collaboration more straightforward. On the other hand, studying collaboration patterns between science disciplines helps to understand the diversity of collaboration behaviors and increases knowledge fusion (Xie, Li, Li, Duan & Ouyang, 2018). In addition, due to the significance and role of hot papers in the research system considering the emphasis of the regulations on the promotion of faculty members on the collaboration of authors in research works and writing articles, and regarding the importance of the field of science and its place in the priorities of the science and technology map, it would be proper to investigate that in the structure of the co-authorship network of the researchers of hot papers in the field of science, which countries are an essential global collaborator in terms of active publications, universities, and institutions, and to determine the top researchers of hot papers in the field of science. Moreover, it would be better to investigate what is the status of producing hot papers based on the WOS database from 2012 to 2021, how are the authorship pattern and the way of collaboration of researchers of hot papers in the field of science, and how much is the value of CC of these researchers?

Literature Review

A literature review indicates that several national and international research works have drawn the co-authorship network of papers, some of which are briefly mentioned in the following.

Webster, Jonason, and Schember (2009) analyzed the Hot topics and popular papers in evolutionary psychology: Analyses of title words and citation counts in Evolution and Human Behavior, their results indicated that the 20 most-cited articles in these journals show the

importance of research teams. In another study, Afshar et al. (2009) evaluated authors' collaboration levels in the Scientometrics Journal articles from 2004 to 2008. Their results indicated that 1435 authors have collaborated on 615 articles, the average number of authors for each article was 33.2, and the CC of the authors was equal to %60.

Osareh, Serati, and Khdemi (2014) investigated the co-authorship network of Iranian researchers in the field of pharmacology and pharmaceuticals in the WOS database from 2000 to 2012. The CC of these publications was % 7, and the highest rate of global collaboration is related to the researchers from the United Kingdom, United States, and Canada. Moreover, the co-authorship network of researchers consisted of 90 nodes (authors), and the degree of density of this network was equal to % 084. Glinni-Moghadam and Taheri (2015) investigated the status of the co-authorship network and CC of Iranian scientific researchers in space science in the science citation index from 1 January 2014 to the end of that year. Their findings indicated that among 2501 indexed articles, %45.67, %,24.4 and %55.32 were produced with national, regional, and international collaborations, respectively. Moreover, higher than %88 of the articles have two-author (%27.35) and three-author (%39.16) patterns.

Pourkarimi Daranjani, Glinni-Moghadam, and Jalali Dizaji (2016) analyzed the scientific collaboration levels of Iranian researchers in the WOS database. Their findings demonstrated that the average CC of authors in the studied period was % 64, with an upward trend. Zhao and Wei (2017) found that Chinese scientists pay more attention to inter-organizational, inter-regional, and international collaboration and publish higher-quality articles. The investigation of the collaboration status of Chinese scientists in international articles will help them to understand the conditions of international collaboration. The articles published by Chinese researchers from WOS were the inclusion criteria for this work; the increase in the collaboration rate of Chinese scientists from %50 in 1992 to %92.53 in 2016 was concluded. In addition, the collaboration rate was related to two- to five-authorship patterns.

Tajedini, Soheili, and Sadatmoosav (2018) analyzed the structure of co-authorship networks of researchers using individual-oriented and collective-oriented approaches and then investigated the relationship between centrality metrics and the citation performance of researchers. The type of results indicated that the average number of co-authors per article was equal to 2.8 per article, and the percentage of co-authored articles compared to single-authored ones was 89.4%. Alipour, Siheili, Ziaei, and Khasseh (2020) analyzed the structure of knowledge organization studies based on co-authorship network analysis of articles on the Web of Science. The results showed that the single-authorship pattern (%49.93) and double-authorship pattern (%34.68) were the most common approaches in knowledge organization studies, and it seems that compared to other fields, there were no acceptable scientific collaborations among knowledge organization authors.

Zamani and Maleki Borjlou (2021) analyzed the scientific productions of Qom University, emphasizing the co-authorship of researchers. The results indicated that the highest pattern of co-authorship was obtained for three-author, two-author, and four-author productions, demonstrating that Qom University researchers have shown a great desire for scientific collaboration and co-authorship. In addition, the CC in the research works of Qom University in WOS was equal to 0.581. Moreover, the collaboration of Qom University was in a favorable situation. Mostafavi and Azh (2023) investigated the relationship between International Scientific Collaboration and Citations of Highly Cited and hot papers of Iranian Researchers in the Web of Science Database. The findings show that the relationship between countries

‘researchers' cooperation and the number of citations received by highly cited articles is a strong, positive, and significant predictor

Undoubtedly, scientific collaboration is useful in most cases, and teamwork will lead to the development of scientific relations and, accordingly, the growth of science in various fields. Therefore, conducting research that investigates the relationship of collaboration between authors is essential and can show a better picture of the evolution of scientific collaborations in different fields. The analysis of the mentioned backgrounds indicated that each research piece evaluated co-authorship in different subject areas. Due to the significance of developing a scientific chain and interactions between researchers and taking into account that hot papers have more scientific and research acceptance among researchers than other articles, and on the other hand, in the regulations for the promotion of academic faculty members of universities and higher education institutions and research centers, hot papers published in prestigious journals and indexed in international citation databases have highest scores, as well as the existence of a research gap in the co-authorship network of researchers of hot papers in the field of science based on co-authorship metrics in the WOS, the present investigations were formulated to address the issues as mentioned above.

Research Objectives

Objectives of the study are deliberated according to the exploration of the Co-authorship network to generate enhanced results for the study

1) To find out the structure of the co-authorship network of researchers of hot papers in science.
2) To determine the status of hot papers regarding publications, universities, and active institutions.
3) To find out the most important international countries collaborating with researchers of hot papers in science.
4) To find out the production of hot papers by researchers in the science sub-fields based on the WOS database during 2012-2021.
5) To find out the pattern of authorship and collaboration of researchers of hot papers in science.
6) To measure the co-authorship coefficient of researchers of hot papers in science.

Materials and Methods

A small group of papers is recognized very soon after publication, reflected by rapid and significant numbers of citations. These papers are often key papers in their fields. We use a special filter to detect such "hot" papers. Hot Papers are papers that receive citations soon after publication relative to other papers of the same field and age.

This investigation is a descriptive study using a scientometrics approach in terms of methodology. By applying the co-authorship analysis techniques, this study examines the hot papers in the science citation index of the WOS database. The research population includes 3475 hot papers in the field of science from 2020 to 2021, which are indexed in the WOS citation database. Analysts of the Web of Science and Excel software have been used to analyze the database.

According to the objective of the present study, after examining the backgrounds related to the research field and getting help from experts in information sciences and knowledge

studies, the following search strategy was applied as the basis for extracting research data from the WOS database. Results=3475

Year= (2020-2021) and Science Citation Index Expanded (SCI-EXPANDED) (WOS Index) and Hot

The application of the search strategy is in the way that in the WOS database, we entered the advanced search section and limited the search period to 2020-2021, then selected Hot papers from the Quick Filters menu. Afterward, we selected the Science Citation Index Expanded (SCI-E) option and then selected the other file formats option from the Export section. Then, we used the Full record and citations reports option to save all the records. Finally, all the records were saved in 500-piece delimited tab format (Win). The data of the subject areas of hot papers were taken from the subject category section of WOS, which includes biology and biochemistry, environment/ecology, earth sciences, immunology, material science, mathematics, microbiology, molecular biology and genetics, physics, as well as plant and animal sciences.

The extracted data were imported to Raver Pre-map software to perform analyses related to the purpose of the research. After converting to the suitable format, the authors' names, countries, and other descriptive information of the research data were homogenized and extracted. After performing homogenization for the hot papers of the science citation index, according to the following table, a total of 105 authors were used to develop the co-authorship matrix and draw the co-authorship map.

No.	Research Population	Number of Articles	Total Number of Authors	Number of Authors Selected for the Co-authorship Matrix
1	Hot Papers	3475	47, 045	A total of 105 authors with a minimum publication frequency of 11 articles

The UCINET software was used to analyze the co-authorship map, and NetDraw software was used to draw it.

To investigate the CC of researchers of hot papers, the number of authors of each article was counted by writing a formula in Excel. Then it was divided into several groups, including articles by one author, two authors, and up to ten authors and higher. The value of each group was calculated separately using the CC formula; the descriptions related to the applied tests and formulas are presented in the following.

Statistical Method, Software, and Formulas Used for Data Analysis

Collaborative Coefficient (CC)

The CC of authors is a number between 0 and 1. When this value is higher than 0.5, it indicates that the collaboration between the authors is at a more desirable level, and the closer it is to zero, it indicates a poor level of collaboration (Ajiferuke, Burell & Tague, 1988).

The CC shows the collaboration rate of the researchers; when this value is closer to 1, the collaboration among authors is high, and when this value is toward zero, more single-authored articles are observed. The formula for calculating CC is as follows:

$$C = 1 - \frac{\sum_{j=1}^{K} (1/j) F_j}{N}$$

$$2000 = 1 - \left[(1 \times 3) + \left(\frac{1}{2} \times 20\right) + \left(\frac{1}{3} \times 12\right) + \left(\frac{1}{4} \times 8\right) + \left(\frac{1}{5} \times 2\right)\right] / 45$$

$$= 1 - \frac{3 + 10 + 4 + 4 + 0.4}{45} = 1 - \frac{21.4}{45} = 1 - 0.475 = 0.525$$

Results

The research findings indicated that hot papers in the field of science in the WOS database included 3475 records, consisting of articles from 177 different subject areas, which were retrieved based on the output of the subject category of the WOS database. In the following, the results obtained from the data analysis of hot papers in the field of science are presented in the order of the research questions.

Question 1. How is the structure of the co-authorship network of researchers of hot papers in science?

To answer this question, social network analysis and the UCINET software package were applied. At first, the researchers' co-authorship matrix was called with UCINET software, and then the co-authorship network was drawn using NetDraw software.

Figure (1) shows the co-authorship network of researchers of hot papers in science. In this form, each node represents an author, defined as a circle, and the connections between both nodes, shown by lines and called edges, represent the co-authorship of those two authors. In other words, two authors connected by a link have at least one co-authorship in hot papers in the field of science.

The research findings showed that 47,045 authors contributed to the publication of 3475 hot papers in the field of science from 2020 to 2021. Figure (1) indicates the co-authorship network of 105 authors with at least 11 articles. These 105 authors have had a total of 4664 connections with each other. In the map, bold lines indicate the connection or co-authorship of these authors.

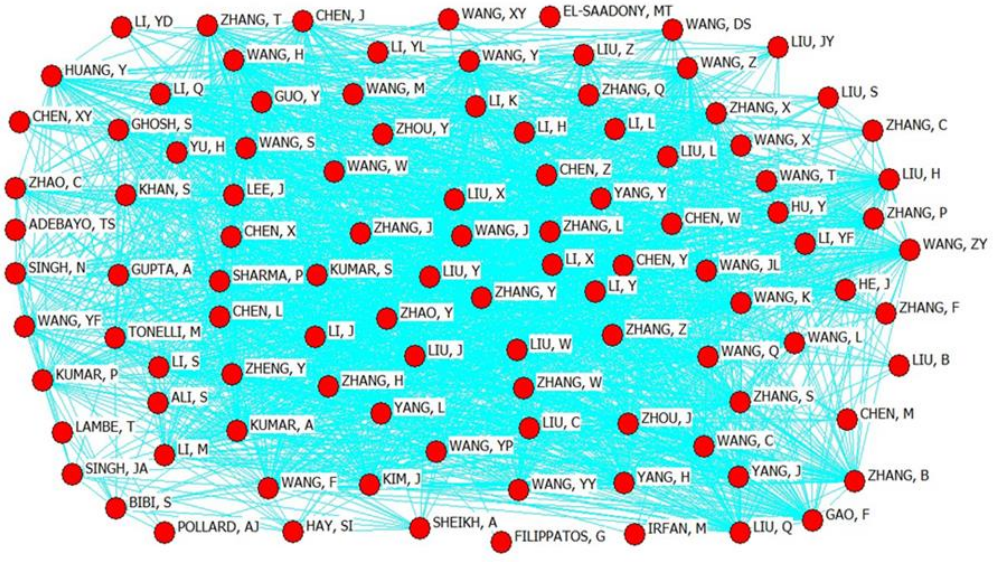

Figure 1: Co-authorship map of 105 authors of hot papers in the field of science from 2020 to 2021.

In Table 1, the information related to the co-authorship of researchers of hot papers in the field of science, with at least 22 co-authorships from 2020 to 2021, is listed in respective order. As indicated in this table, Kumar, R, Tiwari, S; Ghosh, A, Tiwari, S; Ghosh, A; Gupta, A; Ghosh, A, Kumar, R each have had 24 co-authorships, or in other words, joint research works.

Table 1
Information related to the co-authorship of researchers of hot papers in the field of science from 2020 to 2021

Rank	Co-authorship	Freq.
1	Kumar, R / Tiwari, S	24
2	Ghosh, A / Tiwari, S	24
3	Ghosh, A / Gupta, A	24
4	Ghosh, A / Kumar, R	24
5	Gupta, A / Mukherjee, S	23
6	Ghosh, A / Mukherjee, S	23
7	Gupta, A / Tiwari, S	22
8	Gupta, A / Kumar, R	22
9	Kumar, R / Mukherjee, S	22
10	Mukherjee, S / Tiwari, S	22

As shown in Table 2, Liu Y. from China is ranked first with the publication of 53 articles (1.525 %). In addition, Zhang J, Zhang Y, Wang Y, and Wang J ranked second to fifth in terms of frequency of article publication by publishing 46, 44, 38, and 34 articles, respectively. Moreover, the findings demonstrate that all the top authors in science are from China, followed by the United States.

Table 2
Top authors in terms of frequency of article publication

Rank	Author	Freq.	%(3475)	University	Country
1	Liu Y	53	1.525	Xiamen University	Peoples R China
2	Zhang J	46	1.324	University of Texas Southwestern Medical Center Dallas	USA
3	Zhang Y	44	1.266	Zhejiang University	Peoples R China
4	Wang Y	38	1.094	Xi'an Technological University	Peoples R China
5	Wang J	34	0.978	Anhui University of Technology	Peoples R China
6	Zhang L	32	0.921	Zhejiang Normal University	Peoples R China
7	Yang Y	31	0.892	Beijing Normal University	Peoples R China
8	Li J	30	0.863	Tiangong University	Peoples R China
9	Wang L	30	0.863	Northeast Electric Power University	Peoples R China
10	Liu J	29	0.835	Peking University	Peoples R China

Question 2. What is the status of hot papers regarding publications, universities, and active institutions?

The research findings demonstrate that 959 publications and 8741 universities or institutions collaborated in the publication of 3475 hot papers in the field of science from 2020

to 2021. Table 3 indicates the publications with the largest share of hot papers in this period.

Table 3
Publications of hot papers in the field of science from 2020 to 2021

Rank	Pub. Source	Freq.	%	Q	Country	IF
1	Nature	153	4.403	Q1	ENGLAND	69.504
2	New England Journal Of Medicine	137	3.942	Q1	USA	176.079
3	Science	124	3.568	Q1	USA	63.714
4	Lancet	79	2.273	Q1	ENGLAND	202.731
5	Chemical Reviews	73	2.101	Q1	USA	72.087
6	Nature Communications	57	1.64	Q1	ENGLAND	17.694
7	Advanced Materials	52	1.496	Q1	GERMANY)	32.086
8	Chemical Society Reviews	42	1.209	Q1	ENGLAND	60.615
9	Angewandte Chemie International Edition	41	1.18	Q1	GERMANY	16.823
10	Chemical Engineering	40	1.151	Q1	SWITZERLAND	16.744

As shown in Table 3, NATURE journal is ranked first in terms of frequency of article publication, with the publication of 153 articles and a publication share of 4.403. Moreover, the publications named NEW ENGLAND JOURNAL OF MEDICINE, SCIENCE, LANCET, and CHEMICAL REVIEWS, ranked second to fifth with the publication of 137, 124, 79, and 73 articles, respectively. A total of 20 publications had a 30.59% share of publishing hot papers in science. As can be observed, a positive and significant relationship exists between co-authorship and the journal's quartile (Q), and the top 20 hot papers in science have been published in Q1 journals.

A total of ten core universities or institutions in the frequency of publication share in hot papers in science from 2020 to 2021 are presented in Table 4. The total frequency related to the core institutions is equal to 3293. Among these institutions, the UNIVERSITY OF CALIFORNIA SYSTEM has been ranked first with the publication of 297 articles and a publication share of 8.547 compared to other universities and institutions.

Moreover, HARVARD UNIVERSITY, UNIVERSITY OF LONDON, UDICE FRENCH RESEARCH UNIVERSITIES, and CHINESE ACADEMY OF SCIENCES were ranked second to fifth in terms of frequency of article publication, with the publication of 273, 264, 249, and 241 articles, respectively.

Table 4
Universities or institutions as publishers of hot papers in science from 2020 to 2021

Rank	University	Freq.	%
1	University of California System	297	8.547
2	Harvard University	273	7.856
3	University of London	264	7.597
4	Udice French Research Universities	249	7.165
5	Chinese Academy of Sciences	241	6.935
6	University of Oxford	164	4.719
7	University College London	158	4.547
8	University of Texas System	156	4.489

Rank	University	Freq.	%
9	Centre national de la recherche scientifique (CNRS)	154	4.432
10	Harvard Medical School	149	4.288

Question 3. Which are the most important international countries collaborating with researchers of hot papers in science?

The findings indicated that 144 countries collaborated in the publication of 3475 hot papers in the field of science from 2020 to 2021. Table 5 shows the 10 countries with the largest share of hot papers in the field of science, which are presented in the order of frequency and frequency percentage.

Table 5
Leading global collaborating countries in publishing hot papers in science

Rank	Country	Freq.	(% of 3475)
1	USA	1482	42.647
2	China	1358	39.079
3	England	670	19.281
4	Germany	519	14.935
5	Australia	418	12.029
6	Canada	377	10.849
7	France	371	10.676
8	Italy	342	9.842
9	Spain	296	8.518
10	Netherlands	272	7.827

The United States ranked first among the publishing countries with 1482 articles and a publication share of 42.647. Moreover, China, England, Germany, and Australia ranked second to fifth with the publication of 1358, 670, 519, and 418 records, respectively. The ten countries listed in Table 5 accounted for 73% of publications. Furthermore, research pioneers' report related to highly cited scientific articles between 2016-2021 points out that the United States in seven fields and China in four scientific fields (agricultural and animal sciences, materials, environment, chemistry, and physics) have been introduced as leading countries in the world[1].

In the present study, by investigating the co-authorship of hot papers in the field of science, it was determined that China ranked first in terms of the number of top authors in this field with a frequency equal to 1.525, and this country ranked second, after the United States, among the leading countries in terms of international collaboration in publishing hot papers in the field of science.

Question 4. How was the production of hot papers by researchers in the science sub-fields based on the WOS database from 2012 to 2021?

The field of science, similar to other scientific fields, has a subject sub-set in the WOS database. In Table 6, the subject areas in the field of science are presented in the order of frequency of article publication in these areas.

[1] https://didebanefanavari.com/10787 [in Persian]

Table 6
Frequency of indexed publications of hot papers' researchers in the science based on the WOS database from 2012 to 2021

Rank	Subject	Freq.	(% of 3475)
1	Multidisciplinary Sciences	428	12.317
2	Chemistry Multidisciplinary	339	9.755
3	Medicine General Internal	320	9.209
4	Materials Science Multidisciplinary	265	7.626
5	Environmental Sciences	241	6.935
6	Chemistry Physical	205	5.899
7	Nanoscience Nanotechnology	165	4.748
8	Energy Fuels	159	4.576
9	Biochemistry Molecular Biology	149	4.288
10	Public Environmental Occupational Health	142	4.086

The findings indicate that the subject areas of hot papers in the field of science from 2020 to 2021 include 177 subject areas; ten items are listed in the order of frequency in Table 6. As indicated in this table, the subject area of Multidisciplinary Sciences is ranked first with a frequency of 428 compared to other subject areas. Subsequently, the subject areas named Multidisciplinary Chemistry and General Internal Medicine were ranked second and third with a frequency of 339 and 320, respectively.

Question 5. What is the pattern of authorship and collaboration of researchers of hot papers in science?

The investigation of the co-authorship patterns of researchers of hot papers in the field of science from 2020 to 2021 demonstrated that there were 138 co-authorship patterns; due to the high number, the number is limited to 20 co-authorship patterns listed in Table 7.

Table 7
Frequency distribution of authors of hot papers in science from 2020 to 2021

The pattern of authorship	Single Authored Paper	two	Three	Four	Five	Six	Seven	Eight	Nine	Ten
Frequency	63	215	302	355	335	309	209	184	142	129
The pattern of authorship	11	12	13	14	15	16	17	18	19	20
Frequency	95	92	74	70	73	50	42	41	945	48

As shown in Table 7, the collaboration pattern of single-authorship with a frequency of 63 is the lowest, and the collaboration pattern of five-authorship with a frequency of 335 is considered the highest.

Question 6. How much is the co-authorship coefficient of researchers of hot papers in science?

By examining the data obtained from the research findings and using the CC formula, the CC of the researchers of hot papers in the field of science was calculated.

The following formula was used to calculate the authors' CC.

$$CC= 1- \frac{\sum_{j=1}^{K} (1/j) F_j}{N}$$

Where CC is the collaboration coefficient, Fj denotes the number of research articles with an author that were published in a specific period, j implies the authored articles (one-author, two-author, three-author, etc.), N denotes the total number of research articles published in the same period, and K is the maximum number of authors for each article.

The collaborative coefficient is a number between 0 and 1; the closer this number is to 1, it indicates that more authors collaborate.

Table 7 and the calculation of CC in the present research demonstrate the tendency of the authors and researchers of hot papers in the field of science to scientific collaboration and the production of science in a collaborative way. The findings of the present research indicated that the average level of the CC of the authors in writing hot papers in the field of science from 2020 to 2021 is equal to 0.81, which indicates that the authors of the studied hot papers had a high tendency to produce joint works.

$$CC= 1- [(1*63) + (\tfrac{1}{2} * 215) + (\tfrac{1}{3} * 302) + (\tfrac{1}{4} * 322) + (\tfrac{1}{5} * 335) + (\tfrac{1}{6} * 309) + (\tfrac{1}{7} * 209) + (\tfrac{1}{8} * 184) + (\tfrac{1}{9} * 142) + (\tfrac{1}{10} * 129) + (\tfrac{1}{11} * 1265)]/3475$$

$$= 1 - \frac{63 + 107.5 + 100.66 + 80.5 + 67 + 51.49 + 29.85 + 23 + 15.77 + 12.9 + 114.99}{13475}$$

$$=1-667=0.81$$

Discussion

Due to the nature of different disciplines and their differences, the level of scientific collaboration and collaboration in various fields is different. Lee and Bozeman (2005) indicated that there is a close and direct relationship between science production and scientific collaboration. It means that the more scientific collaboration is, the higher the scientific production rate. The results of the present study regarding the structure of the co-authorship network of hot papers in the field of science showed that 47,045 authors were involved in the publication of 3475 hot papers in the field of science from 2020 to 2021, which indicates a high rate of connection or co-authorship of these authors. These results are consistent with the results of Osareh, Serati and Khademi (2014) and Tajedini et al. (2019).

The results of the present research regarding the active researchers in the field of science indicate that among the researchers, Mr. Liu Y with 53 co-authored works from China, Zhang J with 46 co-authored works from the United States, and Zhang Y with 44 co-authored works from China, had the most scientific collaboration and were also the most active researchers in this field.

The findings of the present research regarding the journals that collaborated the most in the publication of scientific products and hot papers in the field of science in the WOS database during 2020-2021 indicated that the NATURE journal from the United Kingdom, with a total of 153 records and the publication share of 4.403 allocated the largest share of documents in the studied period, followed by the NEW ENGLAND JOURNAL OF MEDICINE with 137 records (3.942) and the SCIENCE journal from the United States with 124 records (3.568). The top journals in the quarter of reviewed journals had a Q1 rank, and their impact factor was

higher than 6, which indicates the high quality of the journals.

Furthermore, the findings demonstrated that 144 countries collaborated in the publication of 3475 hot papers in the field of science in 2020-2021. The United States published 1482 articles, and its share of publication was 42.647 among publishing countries. China was in second place with 1358 articles. The findings of this part of the research are consistent with the results of the pioneering global report of the United States and China, which was conducted by reviewing highly cited scientific articles[2].

Among the active institutions and universities collaborating in hot papers in the field of science, the University of California, Harvard University, and the University of London were ranked first to third in this field, with frequencies equal to 297, 273, and 264, respectively. A total of ten subject areas, which have been of interest to researchers and authors of hot papers compared to other subject areas, included multidisciplinary sciences, multidisciplinary chemistry, general internal medicine, multidisciplinary materials science, environmental sciences, physical chemistry, nanotechnology, energy fuels, biochemistry, molecular biology, and public occupational health. In an investigation conducted by Rahimi and Didghah (2010), the subject areas of hot papers in Middle Eastern countries indicated that engineering fields were ranked first, and chemistry, clinical medicine, physics, mathematics, molecular biology, and genetics were the ranks, in respective order.

The investigation of the co-authorship pattern of researchers of hot papers in science from 2020 to 2021 indicated 138 co-authorship patterns, and most of the articles were published in collaboration. It was also found that among the co-authorship patterns of researchers of hot papers in the field of science from 2020 to 2021, most of the articles during the studied years were related to the five-author pattern of collaboration. These results are in line with the research of Moradi (2017) and Tajedini et al. (2019).

The calculations related to the CC of the researchers during the mentioned years indicate that this index had a high value on average during the years 2020-2021. The average of the CC of authors in the authorship of hot papers in the field of science from 2020 to 2021 was equal to 0.81, which indicates that the authors of hot papers had a great tendency to produce joint works and the tendency of researchers to co-authorship is much higher than to single-authorship. These results are consistent with the results of Pourkarimi Daranjani et al. (2016) and Tajedini et al. (2019).

Conclusion

In a general summary, it can be concluded that the willingness of the authors of hot papers to collaborate is high. In addition to the novelty and originality of the subject, the high collaboration of the authors of hot papers in the science citation index is considered one of the reasons for increasing the visibility of articles. Moreover, the CC obtained in hot papers in the field of science during the studied years indicates the high level of scientific collaboration among the reviewed articles, and it is found that the high tendency of authors in this field towards collaboration compared to other disciplines may be due to various reasons. One of these reasons is the nature of executive research in this field, which requires teamwork because the measures in this field have an applied and experimental nature, and for the provision and use of laboratory equipment, high costs must be incurred. Therefore, collaboration among the

[2] https://didebanefanavari.com/10787 [in Persian]

authors of articles in this field is necessary and considered inevitable to achieve scientific progress. The results show that the high collaboration of the authors of hot papers in the science citation index can be one of the reasons for increasing the level of visibility and the potential for using them.

Recommendations

- Since hot papers in the WOS database represent quality articles in the international arena, it is recommended to compare the number of collaborations of Iranian researchers and their citations in other scientific databases, such as ISC, Scopus, and Google Scholar, and compare their results with the findings of the present study.
- Iranian researchers' scientific interactions with the leading countries in scientific production should be strengthened to enable Iranian universities and institutions to gain top positions in the WOS database.
- Some incentive methods should be used to encourage researchers to conduct teamwork, considering the positive relationship between the number of authors of an article and the citation-related effects of that.
- It is recommended that the factors affecting scientific cooperation and the intellectual-cultural foundations governing it be identified to create more cooperation, dynamism, and participation of Iranian researchers.

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