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A BIBLIOMETRIC ANALYSIS ON NATURE OF SCIENCE: A REVIEW OF THE RESEARCH BETWEEN 1986-2019

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Abstract
The nature of science (NOS) is one of the topics that have been constantly investigated in the field of science education during the last thirty years. The purpose of this study is to conduct a bibliometric analysis of studies focused on the nature of science. With this aim, a total of 799 studies that have been published between 1986-2019 years in science education journals were examined and investigated to determine research trends in this topic. Using the "nature of science" keywords, research articles published between 1986-2019 were gathered from Web of Science Core Collection database and analyzed according to the authors' citation bursts, collaborations, countries, most cited articles, word cloud, and word tree structures. Results have revealed that researchers' interests on the topic increased after 2005 and articles on the NOS were mostly published by three major journals including the Journal of Science Education, Science & Education, and Science Education. Results have also revealed that countries that publish most articles on the NOS are the Unites States of America, Republic of Turkey, and the United Kingdom, while scholars whose most published articles are Abd-El Khalick, N.G.Lederman, and A.Garcia-Cormona. In light of obtained results, implications are made for teaching NOS.

Key words: Bibliometric analysis, nature of science, R-studio.

BİLİMİN DOĞASI ÜZERİNE BİBLİYOMETRİK BİR ANALİZ: 1986-2019 YILLARI ARASI ÖRNEĞİ

Özet
Bilimin doğası fen eğitimi alanında son 30 yılda sürekli araştırılan konulardan biridir. Araştırmanın amacı literatürdeki fen eğitimindeki nature of science (NOS) ilgili yayınlanan çalışmaların bibliyometrik analizini yapmaktır. Bu amaçtan hareketle 1986-2019 yılları arasında Web of Science Core Collection veri tabanında taranan fen, fizik, kimya ve biyoloji eğitimi dergilerinde yayınlanan 799 çalışma bibliyometrik açıdan incelenmiş olup, son 33 yıldaki eğilim ortaya konmuştur. Veri tabanında "nature of science" anahtar kavramı kullanılarak tarama gerçekleştirilmiş ve yıllara ilişkin çalışma sayısı, yıllık ortalama alıntı sayısı, bu konuda en çok

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yayın yapan dergiler ve yazarlar, yazarların atıf patlama değerleri, sorumlu yazarların ülkeleri ve işbirliği durumları, en çok atıf alan makaleler, kelime bulutu ve kelime ağacı yapıları ve işbirliği ağları alt başlıklarında incelenmiştir. Elde edilen sonuçlara göre konuya olan ilginin 2005 yılından sonra arttığı söylenebilir. Bu konudaki çalışmaların en fazla yayınlandığı dergiler; *Journal of Science Education* (f = 153), *Science & Education* (f = 132) ve *Science Education* (f = 72) olduğu görülmektedir. En fazla yayın yapan yazarların Abd-El Khalick (f =17), N.G.Lederman (f = 16) ve A.Garcia-Cormona (f = 14) olduğu görülürken, en çok yayının yapıldığı ülkeler sırasıyla Amerika Birleşik Devletleri, Türkiye ve Birleşik Krallık olduğu görülmektedir.

Anahtar kelimeler: Bibliyometrik analiz, bilimin doğası, R-studio programı.

INTRODUCTION

Currently, it is widely accepted that one of the important elements of scientific literacy is students' understandings of the nature of science (NOS) (Lederman, 1992). Through having an accurate understanding of the NOS by students, it is believed that they will able to more informative in their future when making decisions that require scientific ideas and data (Lederman, 1999). From this perspective, since it is considered that scientific literacy has a role in decisions made by students about their personal and societal problems, considerable importance on NOS has been given by educational reform documents in recent years (Lederman, Lederman and Antink, 2013).

Research regarding NOS in the science education field can be categorized in four ways (Lederman, 1992, p.332). These are: a) determining students' conceptions of NOS, b) designing, implementing and assessing educational programs for developing students' students' conceptions of NOS, c) determining teachers and students' conceptions of NOS and studies for developing these conceptions, d) determining teachers' classroom practices toward NOS and explaining the relationship between teachers' classroom practices and students' conceptions of NOS.

When examined the history of studies on NOS, it can be said that the first study is of Wilson (1954). He emphasized in his study that the existing science education approaches are insufficient in developing students' understanding of NOS and also stressed the need to develop, implement and evaluate teaching programs that will enable students who will be members of a science-literate society to develop their understanding of NOS (Abd-El-Khalick and Lederman, 2000; Lederman, 1992). In the 1960s, it can be noted that the definitions of the nature of scientific knowledge had gradually been made by researchers (Conant, 1961; Klopfer, 1969). Klopfer (1969) defined the nature of scientific knowledge as the developmental nature of scientific research processes and obtaining knowledge in science. Also, Klopfer emphasized the importance of understanding how scientific ideas are developed and emphasized that they are one of the most important components of scientific literacy. Similarly, Kimball (1967) developed a model about the NOS after an extensive literature review. After examining the studies of Kimball on teaching NOS, it can be concluded that the movement of teaching the NOS in the world has gained momentum since the end of the 1960s. During the studies carried out in the 1970s, it appears that the nature of scientific knowledge is categorized by researchers (Showalter, 1974; Rubba and Anderson; 1978). For instance, the study of Cotham and Smith (1981) used the words' tentative and revisionary to describe the nature of

scientific theories at the beginning of the 1980s. In 1990, Lederman and O'Malley (1990) clearly defined the terminology and categories to understand students' perceptions of NOS. However, in the science education literature, there are still some debates on the definitions of NOS among researchers. Although Lederman (2007) suggests using the term "the nature of scientific knowledge" (VASI or VOSI) instead of the nature of science (NOS) to prevent the problem of compliance, it still appears that researchers continue to use the term NOS in their works.

Since NOS are one of the popular research topics in the literature, researchers have investigated various aspects of NOS since it was first investigated. Most of the studies have focused on students' and teachers' understanding of NOS and the impact of various teaching methods on the understanding of NOS. However, a little study has been conducted to review the research studies on NOS. For example, Tsai and Lydia Wen (2005) investigated research trends in science education from 1998 to 2002 and they found that the rate of NOS studies among 802 articles was 8.5% (n=68). In another review study, Lee, Wu and Tsai (2009) conducted a content analysis of publications from 2003 to 2007 in three prominent science education journals and found that the ratio of studies including "Philosophy, history, and nature of science" among 869 articles was 8.2% (n=71). In a study that analyzed articles between 1990 and 2007, Chang, Chang and Tseng (2010) found that NOS was one of the most researched topics with 191 articles after conceptual change and concept maps. Similarly, Medina-Jerez (2018) reviewed a total of 159 articles conducted in Latin America between 1998-2015 and found that Philosophy, History, and Nature of Science was the most studied topic with 30.8%.

Erdaş, Doğan and İrez (2016) reviewed a total of 134 articles and dissertations on NOS conducted in the Republic of Turkey between 1998-2012 and their results revealed that although there were many studies conducted on NOS, students and teachers had insufficient knowledge and misconceptions regarding NOS. In a recent study, Ye, Chen and Kong (2019) analyzed the research on science teacher in Web of Science Core Collection and their findings showed that NOS is one of the most used keywords that are used by researchers and noted that research trend on NOS is continuing in the 21st century.

In our study, we analyzed all research on NOS between 1986-2019 using bibliometric analysis. Bibliometric was first described by Pritchard (1969) as "application of mathematical and statistical methods to books and other communication tools". It is also an effective method to analyze the research

trend of a particular area (Shi et al., 2019). It is suggested that bibliometric analysis is a very effective method in determining and evaluating subject areas, journals, and research topics (Huang, Ho and Chuang, 2006). With bibliometric analysis, it is possible to categorize the publications in a specific area according to their characteristics such as the number of citations, author name, journal title, country, institution, article type, and research fields. From this perspective, bibliometric analysis is a method that allows having a reliable conclusion in a specific area or topic concerning trends, social networks, and collaborations. The bibliometric analysis allows also peer-reviewed journals to make their internal evaluations and publication policies. Besides, it provides an opportunity for researchers to obtain more detailed information about the subject areas they study (Kim and Chen, 2015). Bibliometric research and meta-analysis research are different methods. While meta-analysis research aims to arrive at a single general conclusion by bringing the conclusions of different studies together and analyzing them systematically (Cobo et al., 2011), bibliometric research is based on analyzing different studies bibliographically. Bibliometric analysis is a method that helps to summarize and to interpret existing information.

When examined the aforementioned studies, it can be noted that the existing studies analyze research trends in the science education field. In recent years, while bibliometric studies are used to analyze research trends and review research studies in a specific topic, interestingly, no bibliometric study has been found on NOS in the literature. In this context, a bibliometric analysis on NOS will be beneficial for researchers to provide very insightful information and a holistic perspective for their future research. Because of this reason, the purpose of this research is to review and analyze NOS studies between 1986-2019.

METHODOLOGY

To answer the research question, a descriptive research method was used in this study. This method can be defined as the description of a particular event, phenomenon, or situation with its existing features. Articles used in this research were examined through document analysis. The data consisted of articles published on NOS in the Web of Science Core Collection database between 1986-2019 years. Because the first article on NOS was published in 1986 (Lederman, 1986), we have included articles published after this date in our analysis. Since the year 2020 has not been completed yet, studies relating to this year are not included in our analysis. As suggested by researchers (Cobo, López-Herrera, Herrera-Viedma and Herrera 2011; Kim and Chen, 2015; Kurtulus and Tatar, 2021), the most important data sources in the bibliometric

studies are international citations indexes such as Science Citation Index (SCI), Social Science Citation Index(SSCI), and Art & Humanities Citation Index (A&HCI). In this study, since it is compatible with the bibliometric analysis system run through the R program, the Web of Science Core Collection database was chosen for data collection. Using this database, a total of 860 studies have been reached by scanning the keyword "nature of science" and "science education". After making some restrictions during the search on the database, a total of 799 studies was involved in the analysis. Of these studies, 641 were articles, 1 as books, 65 as book chapters, and 91 as proceeding papers. In the analysis, the distribution of these studies according to years, the average number of quotations, the most published journals, the most published authors, the citation burst values, the scientific productivity of the countries, the most cited sources, common citation networks, word cloud, and word tree structures were examined.

To analyze the obtained data, the R-Studio program was used. This program is provided on its official website at https://cran.r-project.org/. This package program used in bibliometric analyses is quite beneficial for quantitative research (Aria and Cuccurullo, 2017). The use of the R program for bibliometric analyses was chosen because it allows having more findings and detailed representation.

For analyses, a data file was prepared from the articles obtained from the Web of Science Core Collection database according to the research criteria. Later, export, other file formats, records from (1-500), record content (Full Record and Cited References) commands were chosen respectively.

Since the data file contained 799 studies and the system can download up to 500 works, the "plain text" option was selected and articles between 1-500, then 501-799 were drawn and merged separately. Then, the "bibliometric" package was downloaded and activated through the R-Studio program. When running the "bibliometric package on the R-Studio, a syntax named "biblioshiny" appeared in the "console" section of the program. After this syntax was copied and pasted on the source, the "run" option was operated. Further, the R-Studio program was directed to the bibliometric analysis page via an address. In the next step, a "plain text" file was uploaded to the data section and analyzes were conducted.

FINDINGS

The distribution of studies according to years is shown in Table 1.

Table 1.The distribution of studies according to years

Year	Number of Articles (f)	Percent (%)
1986-1990	4	0.51
1991-1995	18	2.25
1996-2000	34	4.25
2001-2005	62	7.75
2006-2010	151	18.91
2011-2015	264	33.04
2016-2019	266	33.29

When the table is examined, it can be noted that the first study on NOS was published in 1986 and most studies were between 2016-2019 (n=266). In addition, the studies published after 2005 consisted of 85.2% of the total publications. The annual average scores of citations are given in Figure 1. As can be seen from Figure 1, the average number of citations per year was highest in 2004.

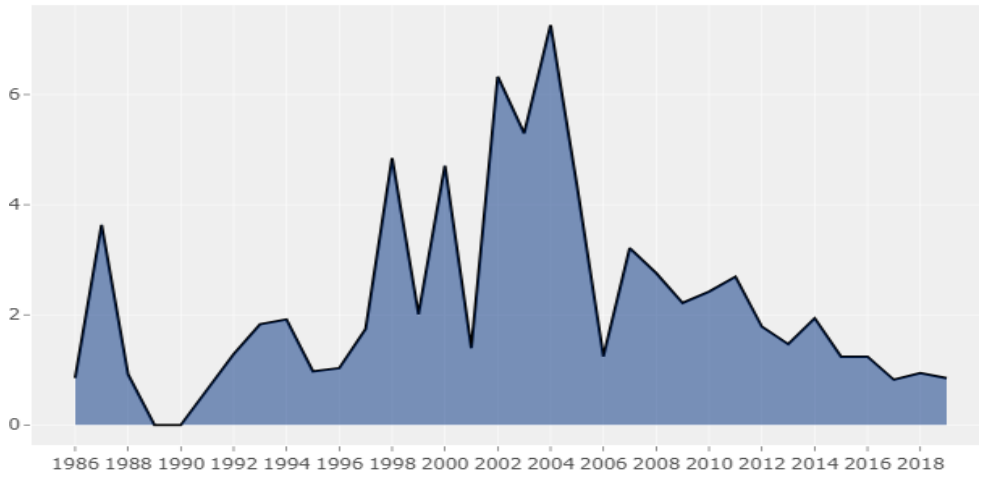

Figure 1. The annual average scores of citations

As shown in Figure 1, the highest increase in the annual average citations is in 2004. Figure 2 displays the journals in which the articles on the key concept were published.

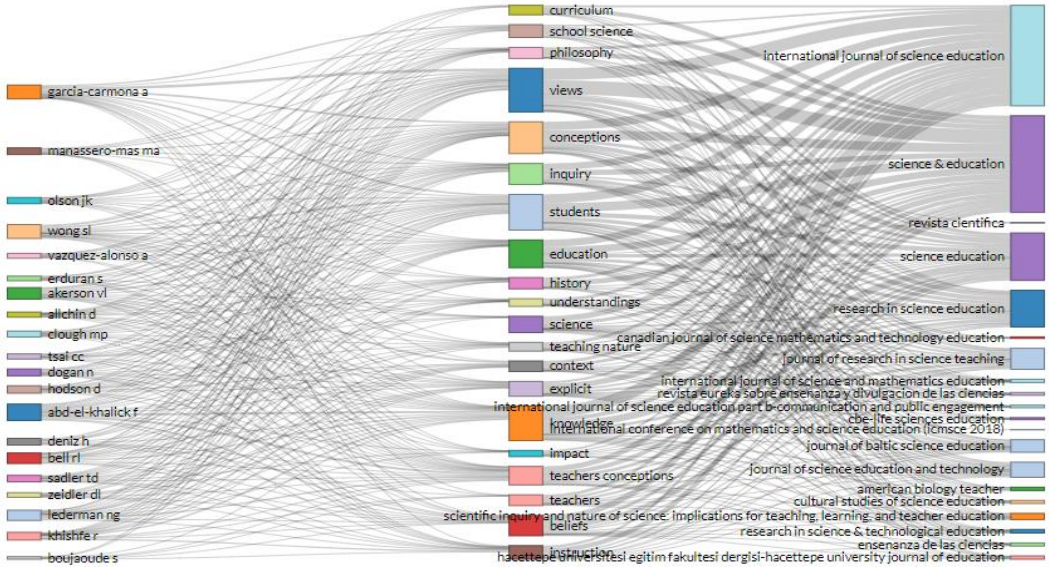

Figure 2. Results on author, keyword, and journal title

Figure 2 shows in which journals the authors published articles according to the keywords. Accordingly, most of the authors used the concepts of "views" and "knowledge". Figure 3 presents a list of top peer-reviewed twenty journals that publish the most articles on NOS.

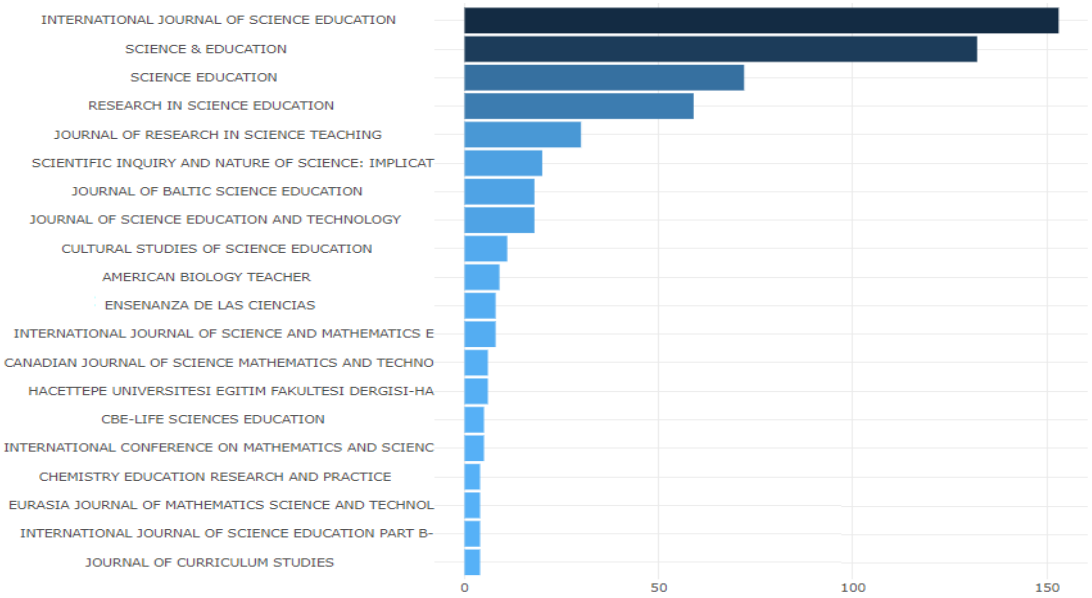

Figure 3. Top 20 peer-reviewed journals that publish the most articles on NOS

As can be seen from the figure, the most published articles on NOS are International Journal of Science Education (n = 153), Science & Education (n = 132), and Science Education (n = 72). Figure 4 shows a list of the authors with the highest number of articles published on NOS.

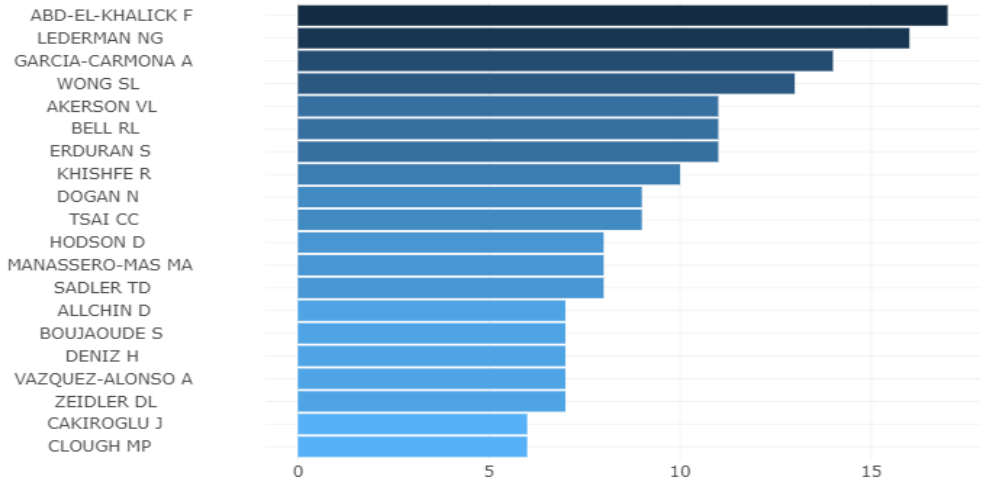

Figure 4. The authors with the highest number of articles published on NOS

Accordingly, the highest number of published articles on NOS belongs to Abd-El Khalick (f =17), Lederman (f = 16), Garcia-Cormona (f = 14) respectively. Figure 5 presents the authors' scores regarding citation bursts.

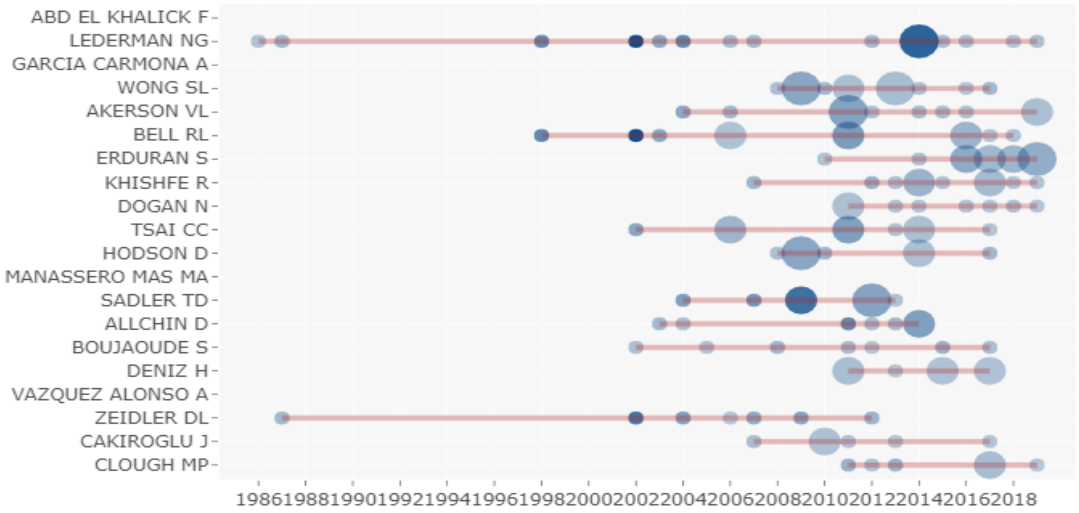

Figure 5. The authors' scores regarding citation bursts

When the citation bursts are analyzed, it was found that two authors have the highest citation burst. The first author is N.G. Lederman with 35.26 between 1986-2019 and the second author is R.L. Bell with 35.26 between 1998-2018. This result means that N.G. Lederman is a featured author in the 33 years. Table 2 presents a list of authors who have the highest citation burst value.

Table 2.The authors who have the highest citation burst value

Authors	Citation Burst Scores	Years	
N.G.Lederman	35.26	1986	2019

R.L.Bell	35.26	1998	2018
T.D.Sadler	25.33	2004	2013
D.L.Zeidler	23.89	1987	2012

From Table 2, it can be noted that the citation burst values of the four authors are quite high. Figure 6 shows the results of the country of the authors.

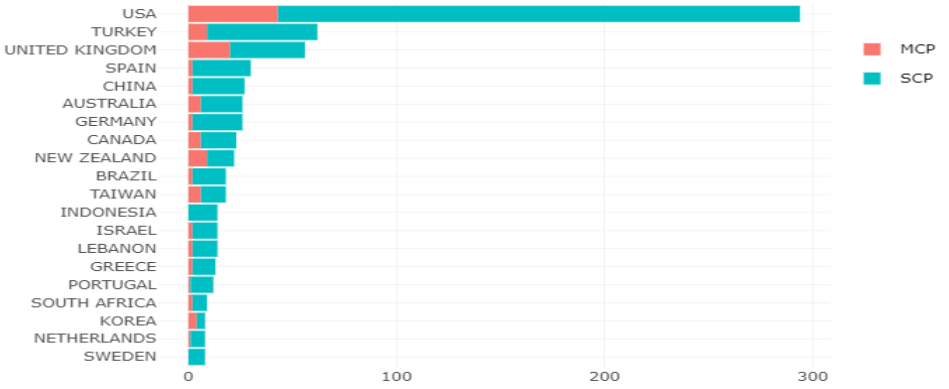

Figure 6. The countries of the authors

While SCP (Single Country Publications) shows the number of publications made by the authors from a single country, MCP (Multiple Country Publications) shows the publications made with more than one country. When we examined the countries of the corresponding authors, it was found that the most authors were from United States (294 articles, SCP:251, MCP:43), Turkey (62 articles, SCP:53, MCP:9), and United Kingdom (56 articles, SCP:36, MCP:20) (Table 3).

Table 3.The countries of the corresponding authors

Country	Number of Articles	Frequency	SCP	MCP	MCP Rate
USA	294	0.37596	251	43	0.1463
Turkey	62	0.07928	53	9	0.1452
United Kingdom	56	0.07161	36	20	0.3571
Spain	30	0.03836	28	2	0.0667
China	27	0.03453	25	2	0.0741
Australia	26	0.03325	20	6	0.2308
Germany	26	0.03325	24	2	0.0769
Canada	23	0.02941	17	6	0.2609
New Zealand	22	0.02813	13	9	0.4091
Brazil	18	0.02302	16	2	0.1111
Taiwan	18	0.02302	12	6	0.3333
Indonesia	14	0.0179	14	0	0

Israel	14	0.0179	12	2	0.1429
Lebanon	14	0.0179	12	2	0.1429
Greece	13	0.01662	11	2	0.1538
Portugal	12	0.01535	11	1	0.0833
South Africa	9	0.01151	7	2	0.2222
Korea	8	0.01023	4	4	0.5
Netherlands	8	0.01023	7	1	0.125
Sweden	8	0.01023	8	0	0

In Table 3, the first 20 countries are included. According to Table 3, although the United States and Turkey are in the first place in terms of the number of articles, it was found that these two countries had the lowest MCP score. Although the number of studies to take first place in the United States and Turkey was determined to have a low rate of MCP. Among these 20 countries, South Korea, New Zealand, UK, Taiwan, and Canada are the countries with the highest MCP rate. This result shows that scholars from South Korea, New Zealand, UK, Taiwan, and Canada are more open to international collaborative works or to work with authors from different countries. On the other hand, it was found that Indonesia, Sweden, and Spain are the countries with the lowest MCP rates. Figure 7 presents the results for the scientific productivity rates of the countries.

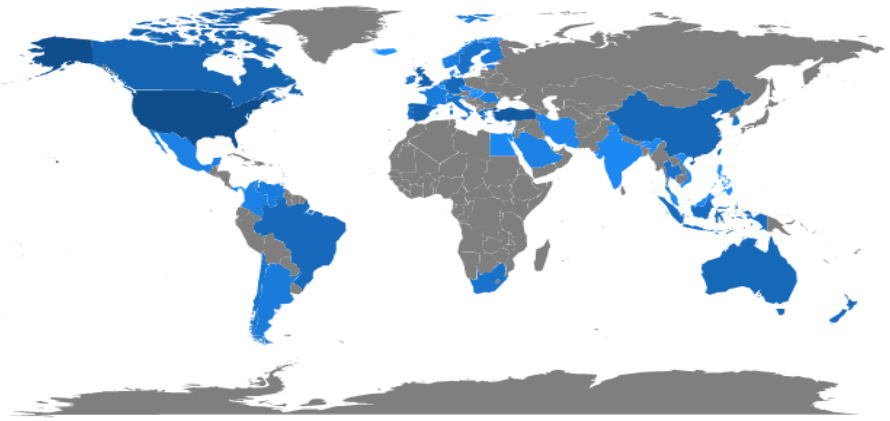

Figure 7. The countries' scientific productivity rates

When Figure 7 is examined, it shows scientific productivity rates according to the countries where NOS studies were conducted. Overall, the figure shows the number of publications from dark blue to light blue. It was found that no publications have been published in the WoS database in gray colored countries. When we looked at the number of publications, we found that the first countries the United States (529 articles), Turkey (127 articles), and the

United Kingdom (88 articles) respectively. Figure 8 shows countries receiving highest citation scores.

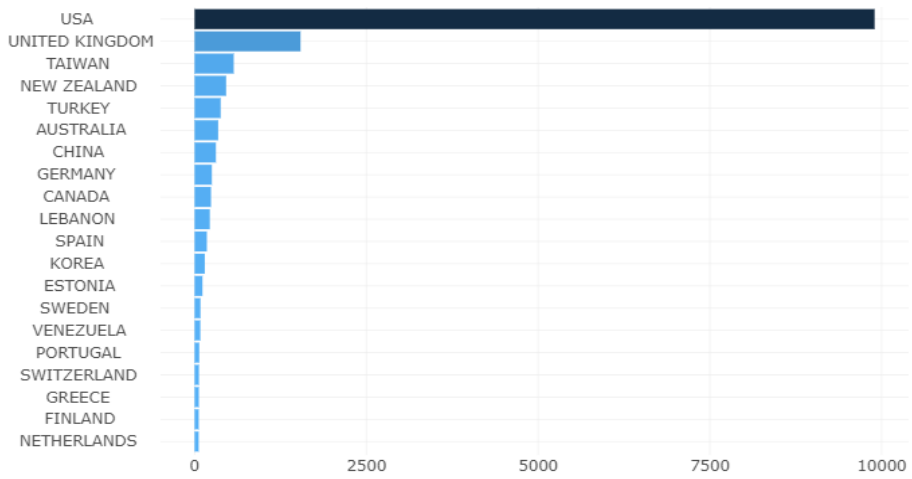

Figure 8. Number of citations based on the country

When Figure 8 is analyzed, it is found that the countries where the most cited articles were written are USA (f = 9897), United Kingdom (f = 1542), and Taiwan (f = 570) respectively. Figure 9 displays the publications that have been cited the most.

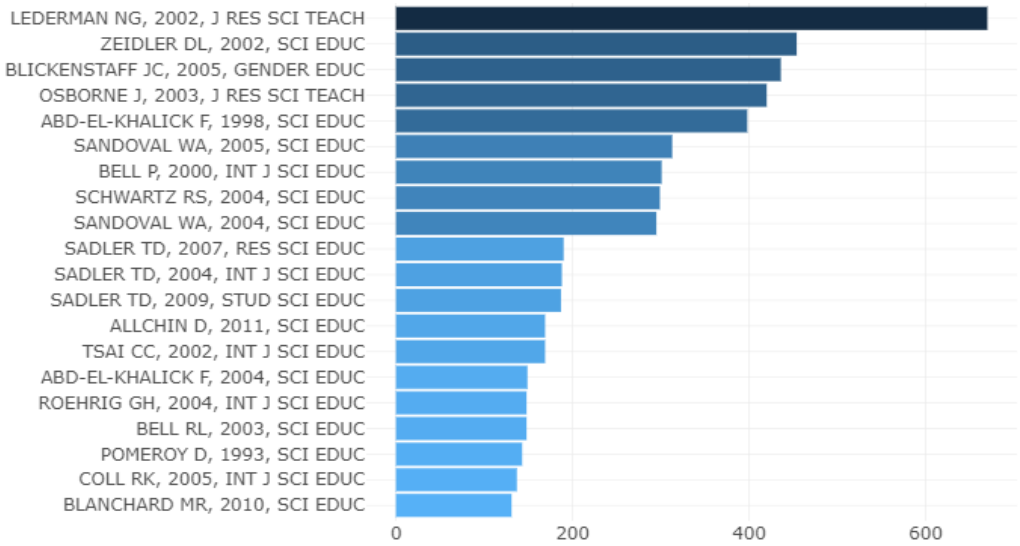

Figure 9. Most cited studies and total citations

When looked at Figure 9, it can be easily concluded that the most cited works belong to Lederman's (2002, 670 citations) article. After that, studies of Zeidler (2002, 454 citations), and Blicken staff (2006, 436 citations) are the most cited by

researchers. Figure 10 presents the most frequently used keywords in the articles.

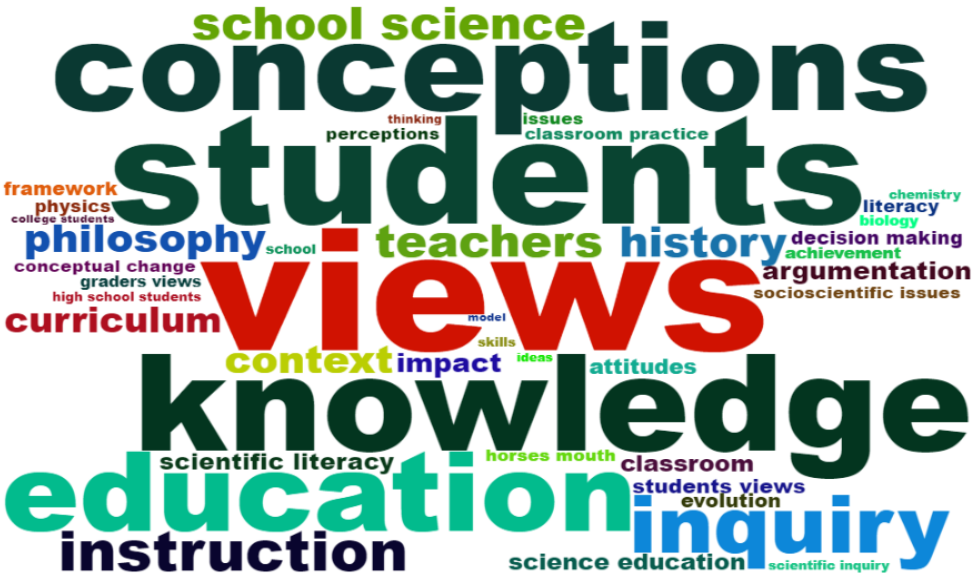

Figure 10. Word cloud of analyzed articles

To determine the most frequently used keywords, the word clouds method was used. As it may be known, Word Clouds which is one of the methods of data mining shows the most used words in a text or paragraph. As it is known, the word in the center shows the most used word specific to that subject area. As the word size decreases and moves away from the center, it indicates that the word is used less frequently. Our findings show that the most used keywords are views (f=206), students (f=182), and knowledge (f=162) respectively. In addition, Figure 11 also shows the most frequently used words in the abstracts of the analyzed articles.

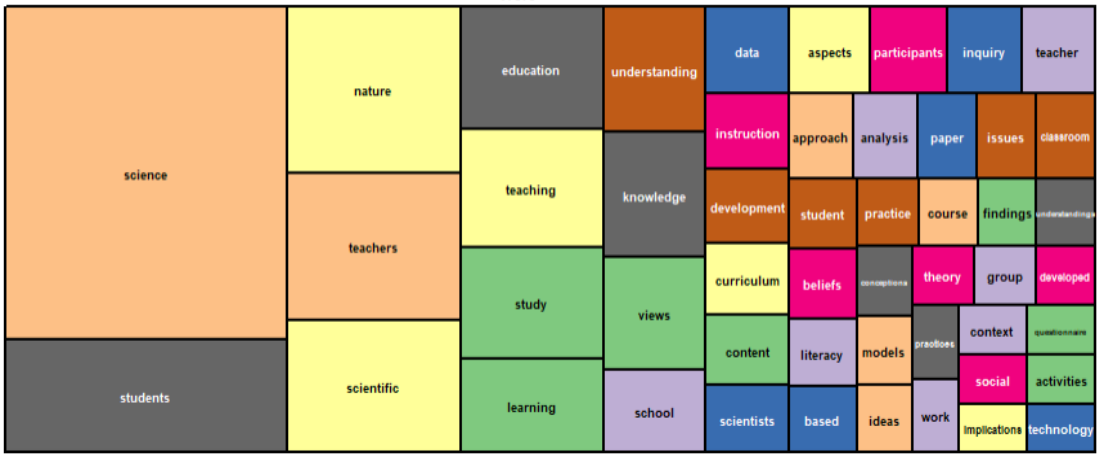

Figure 11. Word tree map of analyzed articles' abstracts

One of the methods of data mining is Word TreeMap. Like to word clouds, this method shows the most used word in a text. When looked at Figure 11, it can be seen that the most used keywords in the abstracts are science (f=4104), students (f=1387), and nature (f=1261) respectively. Figure 12 gives a collaboration network of researchers

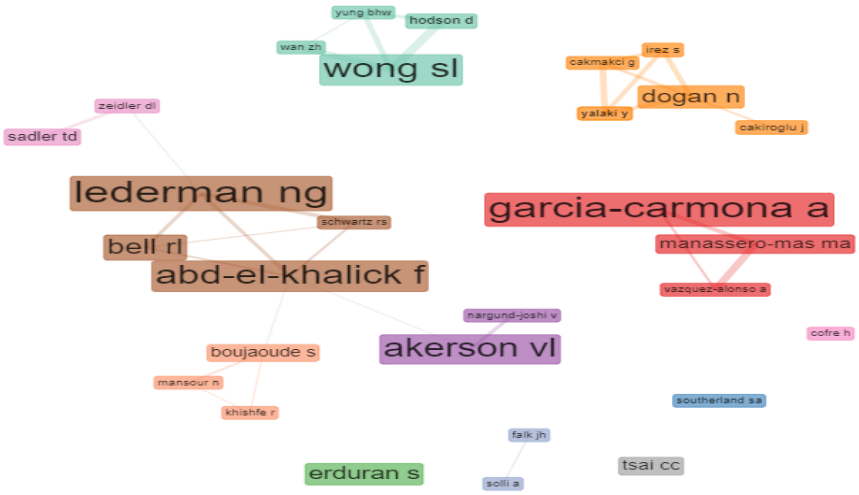

Figure 12. The network of the collaboration of researchers

According to these results, the researchers in the same cluster in Table 4 published on a similar subject.

Table 4. Author-cluster centrality values

Author	Cluster	Author	Cluster
Manassero-Mas MA	1	Cofre H	7
Vazquez-Alonso A	1	Tsai Cc	8
Garcia-Carmona A	1	Yung BHW	9
Southerland Sa	2	Hodson D	9
Erduran S	3	Wong Sl	9
Akerson Vl	4	Wan Zh	9
Nargund-Joshi V	4	Khishfe R	10
Yalaki Y	5	Boujaoude S	10
Dogan N	5	Mansour N	10
Irez S	5	Solli A	11
Cakmakci G	5	Falk Jh	11
Cakiroglu J	5	Sadler Td	12
Lederman Ng	6	Zeidler Dl	12
Abd-El-Khalick F	6		
Bell Rl	6		
Schwartz Rs	6		

For example, when the studies of the 6th cluster authors in the table are examined, it can be noted that the study areas are oriented towards the same subject area.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to conduct a bibliometric analysis of studies focused on NOS. For this aim, a total of 799 studies that have been published on NOS in science education journals were analyzed using bibliometric analysis through the R-Studio program. For the data analysis, the distribution of studies according to years, the number of quotations, most published authors, citation bursts, articles of the countries, most cited articles, collaborations, word clouds, and word trees were considered.

Results have indicated that the first article on NOS in the database was published by Lederman (1986). Results have also indicated that the number of studies on NOS increased after 2005. In particular, the studies at the highest rate were published between 2016-2019. Most studies (n=73) on NOS were conducted in 2019. On the other hand, the highest rate of annual average citation rate belongs to 2004 when 11 articles were published on misconceptions. The journals that publish the most articles on NOS were found to be the Journal of Science Education (f = 153), Science & Education (f = 132), and Science Education (f = 72). It was also found that the most published authors were Abd-El Khalick (f =17), Lederman (f = 16), and Garcia-Cormona (f = 14). The countries where most articles are written are the United States, the Republic of Turkey, and the United Kingdom.

Results have also revealed that the most published author on NOS is Abd-El Khalick. This researcher has seventeen articles in the database. The most researched Turkish author who has the most publications on NOS is found to be S. Erduran. She has eleven articles on NOS in the database.

According to citation busts, it was found that an article by N.G. Lederman, F. Abd-El-Khalick, R. Bell and R. Schwartz, in the 2002 year has the most citation bursts. Although another study published by D.L. Zeidler, K.A. Walker, W. A. Ackett and M.L. Simmons in 2002 is not among the first articles in terms of citation burst, it has a high citation burst value.

RECOMMENDATIONS

In light of the results obtained from this research, some suggestions can be made for researchers:

1. Because views of students, preservice teachers, and teachers of NOS has importance for researchers, it is recommended to continue research on this subject.
2. Bibliometric analysis studies will guide researchers in determining trend topics in science education and helps to facilitate to reach all research on a topic.
3. In this study, the Web of Science Core Collection database has been used. Further studies should be involved in other databases including ERIC, Scopus, and ProQuest so that conference papers and dissertations can be examined.
4. In this study, studies between 1986-2019 were involved in the analysis. Further studies can be done by using the previous date ranges.

ACKNOWLEDGEMENTS

I wish to dedicate this article to my colleague Professor Norman LEDERMAN who died in 2021. He gave me faithful support and encouragement during the writing of this article and made major contributions to the nature of science.

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