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A Bibliometric Review on Spatial Ability Studies in Education

Eğitimde Uzamsal Yetenek Çalışmaları Üzerine Bibliyometrik Bir İnceleme

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ABSTRACT

This study aims to bibliometrically examine the published scientific documents on spatial ability in the field of education. Within the scope of the research, a scan was performed using the formula -"spatial abil*" and "educat*"- in the Web of Science (WoS) database. VOSviewer program has been used in the analysis of the data. As a result of the analysis, 1317 scientific studies published between 1975-2022 were reached. The first study published in WoS in the related subject area belongs to the year 1984. Most of the publications on the concept of spatial ability, which began to gain popularity as of the 2000s, were produced in 2020. The country that produces the most publications, has the strongest relationship network, and receives the most citations is the USA. The organization with the strongest relationship network is Tomsk State University, the organization with the most publications is La Laguna University, and the organization with the most citations is Vanderbilt University. The scientific document with the strongest relationship network and the most cited is Wai et al. (2009). The scientific resource with the strongest citation relationship and the highest number of citations is the Journal of Educational Psychology.

Keywords: Bibliometric analysis, Collaboration, Education, Network analysis, Spatial ability

ÖZ

Bu çalışmada, eğitim alanında uzamsal yetenek ile ilgili yayınlanmış bilimsel belgelerin bibliyometrik olarak incelenmesi amaçlanmaktadır. Araştırma kapsamında Web of Science (WoS) veri tabanında -"spatial abil*" and "educat*"- formülü kullanılarak tarama gerçekleştirilmiştir. Verilerin analizinde VOSviewer programı kullanılmıştır. Analiz sonucunda 1975-2022 yılları arasında yayınlanmış 1317 bilimsel çalışmaya ulaşılmıştır. İlgili konu alanında WoS'ta yayınlanan ilk çalışma 1984 yılına aittir. 2000'li yıllar itibarıyla popülerlik kazanmaya başlayan uzamsal yetenek kavramı ile ilgili en fazla yayın 2020 yılında üretilmiştir. En fazla yayın üretilen, ilişki ağı en güçlü olan ve en fazla atıf alan ülke Amerika'dır. İlişki ağı en güçlü olan kurum Tomsk Devlet Üniversitesi, en fazla yayın yapan kurum La Laguna Üniversitesi, en fazla atıf alan kurum ise Vanderbilt Üniversitesi'dir. İlişki ağı en güçlü olan ve en fazla atıf alan bilimsel belge Wai vd. (2009)'dir. Atıf ilişkisi en güçlü olan ve en fazla atıf alan bilimsel kaynak Journal of Educational Psychology (Eğitim Psikolojisi Dergisi) olarak tespit edilmiştir.

Anahtar Kelimeler: Ağ analizi, Bibliyometrik analiz, Eğitim, İş birliği, Uzamsal yetenek

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Introduction

Spatial ability is the ability to represent, transform, produce, and remember non-linguistic symbolic information (Linn & Peterson, 1985, p. 1482). Similarly, Lohman (1996, p. 3) defines spatial ability as the ability to produce, retain, recall, and transform well-structured visual images. As can be understood from the definitions, spatial ability is a complex structure that embodies many skills at the same time. There are different classifications regarding the components of spatial ability in the literature. Ekstrom et al. (1979, p. 84) classify spatial ability as figural fluency, visual memory, speed of closure, and spatial orientation. According to Linn and Peterson (1985, p. 1482-1485), spatial ability consists of three components: spatial perception, mental rotation, and spatial visualization. Carroll (1993, p. 112), by making a more detailed classification, states that spatial ability consists of visualization, spatial relations, closure speed, closure flexibility and perceptual speed components.

Spatial ability appears in many activities from simple to complex in daily life. Activities such as guiding someone, reading a map, using three-dimensional objects, driving in traffic, and making architectural designs all require spatial ability. Therefore, many other areas of knowledge such as architecture, astronomy, biochemistry, biology, cartography, chemistry, engineering, geology, mathematics, music, and physics include spatial ability. The concept of spatial ability, which comes across us at every moment of our lives, is a subject area that has been researched for about 40 years. For this reason, there are many studies in national and international literature. Systematic examination of these studies is important for providing ideas to educators who will receive training or conduct research in the relevant field. There are many meta-analysis (Baenninger & Newcombe, 1989; Di & Zheng, 2022; Höffler, 2010; Linn & Petersen, 1985; Maeda & Yoon, 2012; Reilly & Neumann, 2013; Roach et al. 2020; Vogel et al., 2003; Wang et al., 2014; Xie et al., 2019), meta-synthesis (Korkmaz & Morali, 2022; Sümen, 2019) and systematic review (Garcia et al., 2021; Langlois et al., 2020; McLaughlin & Bailey, 2022; Papakostas et al., 2021; Yuan et al., 2019) studies conducted with the studies in the literature. However, it is noteworthy that there are no studies in the literature in which the author, subject, publication information, cited sources, etc. characteristics of spatial ability publications are examined. These characteristics are called bibliometric characteristics. Examining the bibliometric characteristics of publications contributes to the researcher such as identifying the most productive researchers on a subject, making comparisons between countries, institutions, etc., and how scientific communication is carried out in various disciplines (Al, 2008, p.18; Umut-Zan, 2012, p.15).

Bibliometric studies have a complementary quality to traditional compilation studies. It provides the researcher with useful information about the relevant field (such as important publications, authors, and the structure of the field) (Yılmaz, 2021, p.1477). Analyzing the bibliometric characteristics of scientific studies in literature is important in terms of expanding the relevant literature and shedding light on future studies. For this reason, in the current study, it is aimed to examine the published scientific studies on spatial ability in the field of education bibliometrically. For this purpose, the "What are the demographic and bibliometric characteristics of the scientific publications in the field of education on 'spatial ability' scanned in the Web of Science (WoS) database?" research question has been focused on. In accordance with this research question, the answers to the following sub-problems were searched:

1. What is the distribution of scientific publications on spatial ability in the field of education according to demographic (year, type, language, and country) characteristics?
2. What is the distribution of scientific publications on spatial ability in the field of education according to their bibliometric (collaboration between countries and institutions; the most cited and highly link strength scientific documents, scientific sources, authors; frequency of keywords and link strength) characteristics?

Methods

The current study is a bibliometric review study in which scientific studies published on spatial ability in the field of education and scanned in the Web of Science (WoS) database are examined.

Data Collection Process

To reach the research data, a scan was carried out in the Web of Science (WoS) database (Web of Science Core Collection database provided by Clarivate Analytics, Accessed on: 27.04.2023). The database was searched using the -"spatial abil*" and "educat*"- formula. Since the WoS database archives the studies made as of 1975, all studies published between 1975 and 2022 were included in the present study. The "All Databases" search function was used while scanning.

The criteria used in the selection of scientific publications are as follows:

- scanning of the publication in the WoS database,
- includes the words "spatial abil*" and "educat*" together, and
- to be published before 2023.

As a result of the first scan in the WoS database, 1341 publications were reached. Since the current study aims to examine scientific studies conducted until 2023, the publication year was limited to before 2023. Thus, 24 studies were excluded from the scope and a total of 1317 publications were included in the review.

Data Analysis

As a result of the scanning made in WoS, a total of 1317 scientific studies were reached between 1975-2022. These publications were primarily examined in terms of their demographic (year, type, language, and country) characteristics. The numerical data obtained from the WoS database was transferred to Excel and frequency calculation was performed, and the data were presented visually (graph or figure). Then, the bibliometric characteristics of the scientific publications were examined. The bibliometric analysis method has been used in the analysis of bibliometric characteristics. Bibliometric analysis uses quantitative analysis and statistical methods to reveal the general characteristics of published studies in a particular subject or field (Pritchard, 1969, p.349). The VOSviewer (Version 1.6.18) (CWTS, Leiden, Holland) program was used to perform this analysis. VOSviewer is a software tool for constructing and visualizing bibliometric networks (Van Eck & Waltman, 2017; p.1054). This program uses the VOS (Visualization of Similarities) algorithm to visualize the data (Van Eck & Waltman, 2007). The biggest advantage of this program for the researcher is that it presents the visual presentation to the reader with high quality (Sinkovics, 2016, p. 332). In addition, the program allows for making large-scale scientific network graphs easily understandable (Van Eck & Waltman, 2017). For this reason, the VOSviewer program was preferred in the analysis of bibliometric data.

Results

In this section, the findings obtained from the research are presented.

Demographic characteristics of scientific publications

Published scientific studies on spatial ability in the field of education were examined in terms of year, type, language, and country knowledge. As a result of the examination, 1317 publications were reached. The first publication published in the WoS database belongs to the year 1984. As of the 2000s, the subject area has gained popularity and there has been a noticeable increase in the number of publications. The most publications were produced in 2020 (N=117) (Figure 1).

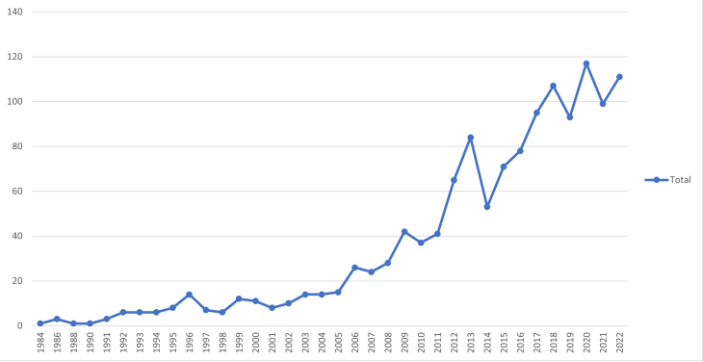

Figure 1.
Distribution of Publications by Years

Most educational publications on spatial ability (N= 1021; 77.53%) were made in the article type. In addition to articles, it has been observed that proceeding papers (N= 224; 17.01%), review articles (N= 69; 5.24%) and book chapters (N= 34; 2.58%) were also frequently produced (Figure 2).

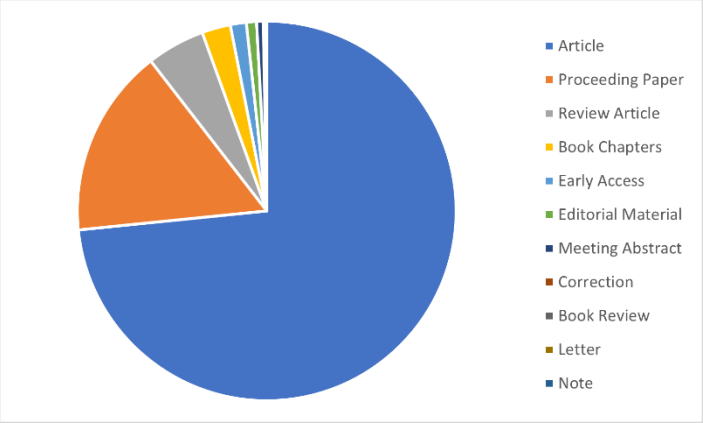

Figure 2.
Distribution of Documents by Publication Types

Almost all the educational studies published in the WoS database on spatial ability (N= 1278; 97.04%) were published in English. In addition to English, it has been seen that publications were produced in ten different languages. These are respectively as follows, Spanish, German, Turkish, French, Portuguese, Chinese, Italian, Russian, Danish, and Polish.

The information about the country where the documents were published was examined and it was found that publications were produced in a total of 82 countries. It has been seen that the country that produced the most publications among these countries is the USA with a total of 424 (32.19%) documents. The USA is followed by Spain

(N= 98; 7.44%), Canada (N= 90; 6.83%), Germany (N= 87; 6.61%) and England (N= 77; 5.85%) respectively (Figure 3).

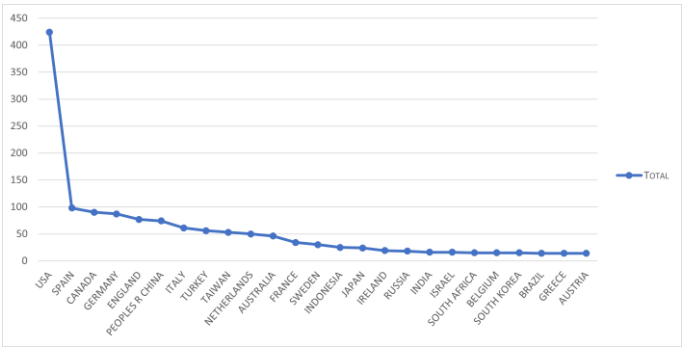

Figure 3.
Distribution of Publications by Country

Bibliometric characteristics of scientific publications

Country collaborations

Spatial ability publications in the field of education were carried out in 82 countries. However, it was determined that 66 of these countries produced publications by collaborating. The image of the cooperation between the countries is given in Figure 4.

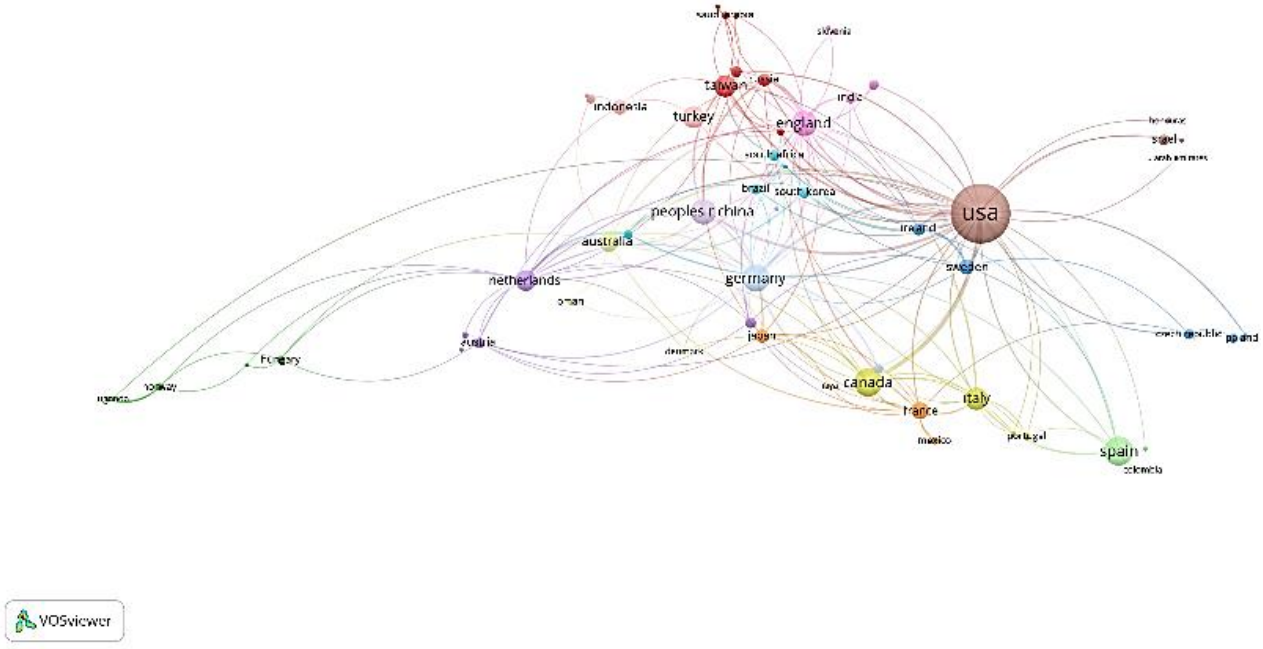

Figure 4.
Country Collaborations

The circle sizes in the image are related to the number of publications in the relevant country. As the number of publications in the country increases, the size of the circle also increases. The lines between the circles show the relationship between countries. Statistical information about the link strength and the number of citations of the cooperating countries has been given in Table 1.

Table 1.
Countries with the Strongest Networks (a) and Most Cited (b)(Top 10 Countries)

Country	Total link strength	Country	Citations
USA	112	USA	13891
England	63	Canada	2288
Germany	49	England	1884
Australia	40	Spain	1709
Canada	34	Germany	1532
Peoples R China	33	Australia	1446
Netherlands	32	Taiwan	1335
Italy	23	Netherlands	1062
France	23	Italy	996
Taiwan	22	Sweden	962
(a)		(b)	

When Table 1 and Figure 4 are evaluated together, the countries with the strongest link network among the countries publishing in the spatial ability subject area are the USA, England, Germany, Australia, and Canada, respectively. Among the countries in the relationship, the most cited countries are the USA, Canada, England, Spain, and Germany, respectively.

Organization collaborations

Scientific studies were carried out in 1356 organizations on the spatial ability subject area in the field of education. However, it was determined that 657 of these organizations produced publications by collaborating. The image of the cooperation between the organizations is given in Figure 5.

Circle sizes are related to the number of publications in the relevant organization, and the circle size increases as the number of publications in the organization increases. The lines between the circles show the relationship between the organizations. Statistical information about the link strength, number of publications and the number of citations of the cooperating organizations is given in Table 2.

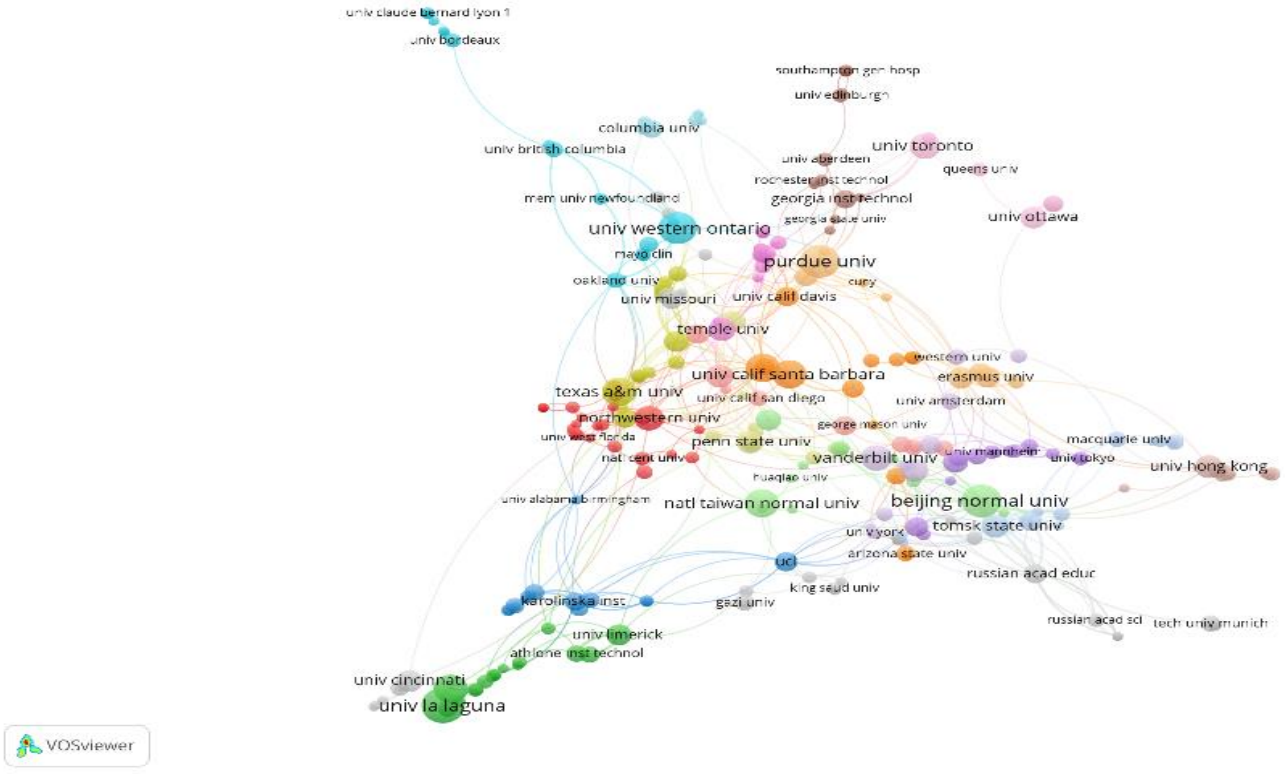

Figure 5.
Organization Collaborations

Table 2.
Organizations with the Strongest Network (a), Most Published (b), and Most Cited (c) (Top 10 Organizations)

Organization	Total link strength	Organization	Documents	Organization	Citations
Tomsk State University	47	University La Laguna	27	Vanderbilt University	2349
Beijing Normal University	42	Beijing Normal University	22	University of California	1171
Russian Academy of Education	35	Purdue University	22	Northwestern University	828
University of London	32	Western University	21	Western University	606
Harvard University	30	University of Illionis	17	Michigan State University	550
Boston University	28	Texas A&M University	17	University La Laguna	536
University New South Wales	28	Universitat Politècnica de València	17	University of Illionis	521
Karolinska Institutet	27	National Taiwan Normal University	17	National Taiwan Normal University	518
Erasmus University	27	University of California	17	University College London (UCL)	506
University of Illionis	26	University of Toronto	14	Karolinska Institutet	452
(a)		(b)		(c)	

When Figure 5 and Table 2 are evaluated together, the organizations with the strongest link network of publications in the field of spatial ability are Tomsk State University (Russia), Beijing Normal University (China), Russian Academy of Education (Russia), University of London (England) and Harvard University (USA), respectively. Among the organizations in relationship, the organizations that broadcast the most are University La Laguna (Spain), Beijing Normal University (China), Purdue University (USA), Western University (Canada) and University of Illinois (USA), respectively. The organizations that receive the most citations among the related organizations are Vanderbilt University (USA), University of California (USA), Northwestern University (USA), Western University (Canada) and Michigan State University (USA), respectively.

Most cited scientific documents

A relationship was found between 914 out of 1317 documents on spatial ability in the field of education scanned in the WoS database. The image of the cooperation between the documents is given in Figure 6.

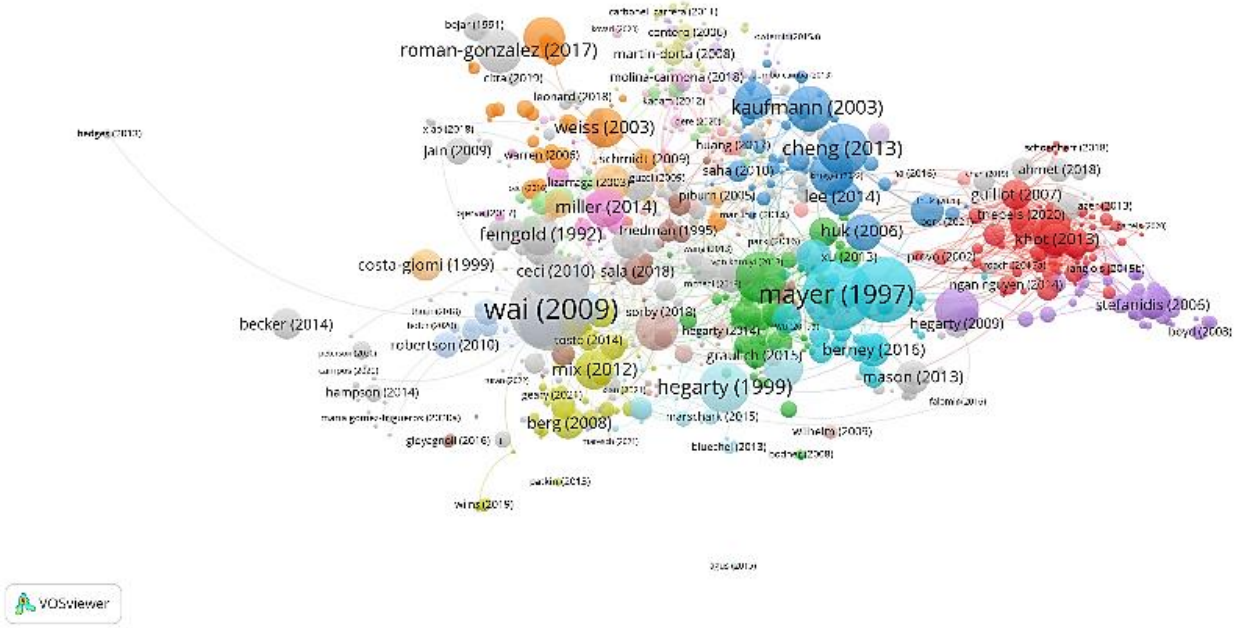

Figure 5.
Most Cited Documents and Co-Cited Network

The sizes of the circles are proportional to the number of citations of the relevant document, and the larger the number of citations to the document, the larger the circle size. The links between the circles show the relationship between the documents. For multi-author studies, only the surname of the first author is used in the image. To be able to read more clearly the documents with the strongest link and the relationship between the documents, the relationship between the first 20 documents with high link strength is presented in Figure 7.

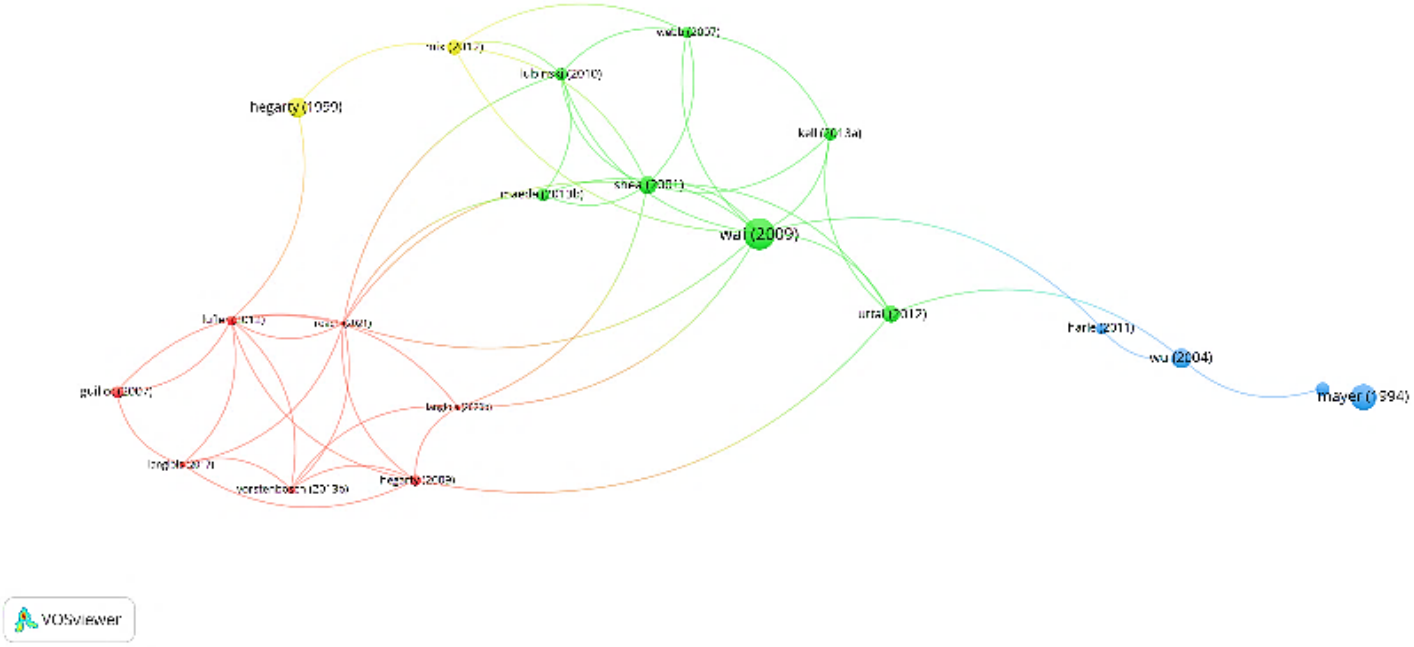

Figure 6.
Most Cited Documents and Co-Cited Network (Top 20 Documents)

Statistical information regarding the link strength and the number of citations of the documents that are in the citation relationship is given in Table 3.

Table 3.
The Strongest Network (a) and Most Cited (b) Documents (Top 10 Documents)[1]

Document	Total link strength	Document	Citations
Wai et al. (2009)	226	Wai et al. (2009)	874
Shea et al. (2001)	88	Mayer (1997)	658
Uttal & Cohen (2012)	66	Mayer & Sims (1994)	562
Guillot et al. (2007)	63	Wu & Shah (2004)	352
Lufler et al. (2012)	63	Cheng & Tsai (2013)	346
Huk (2006)	62	Hegarty & Kozhevnikov (1999)	339
Wu & Shah (2004)	60	Lubinski & Benbow (2006)	305
Mayer & Sims (1994)	54	Kaufmann & Schmalstieg (2003)	281
Hegarty & Kozhevnikov (1999)	52	Shea et al. (2001)	277
Lubinski (2010)	51	Roman-Gonzalez et al. (2017)	269
(a)		(b)	

When the table is examined, the documents with the strongest citation relationship are Wai et al. (2009), Shea et al. (2001), Uttal & Cohen (2012), Guillot et al. (2007) and Lufler et al. (2012), respectively. The documents that received the most citations are Wai et al. (2009), Mayer (1997), Mayer & Sims (1994), Wu & Shah (2004) and Cheng & Tsai (2013), respectively.

Co-citation network of authors

In the field of education, 3913 authors conducted scientific studies on spatial ability. However, it was determined that 2511 of these authors are in the common citation network. The image of the co-citation network between the authors is given in Figure 8.

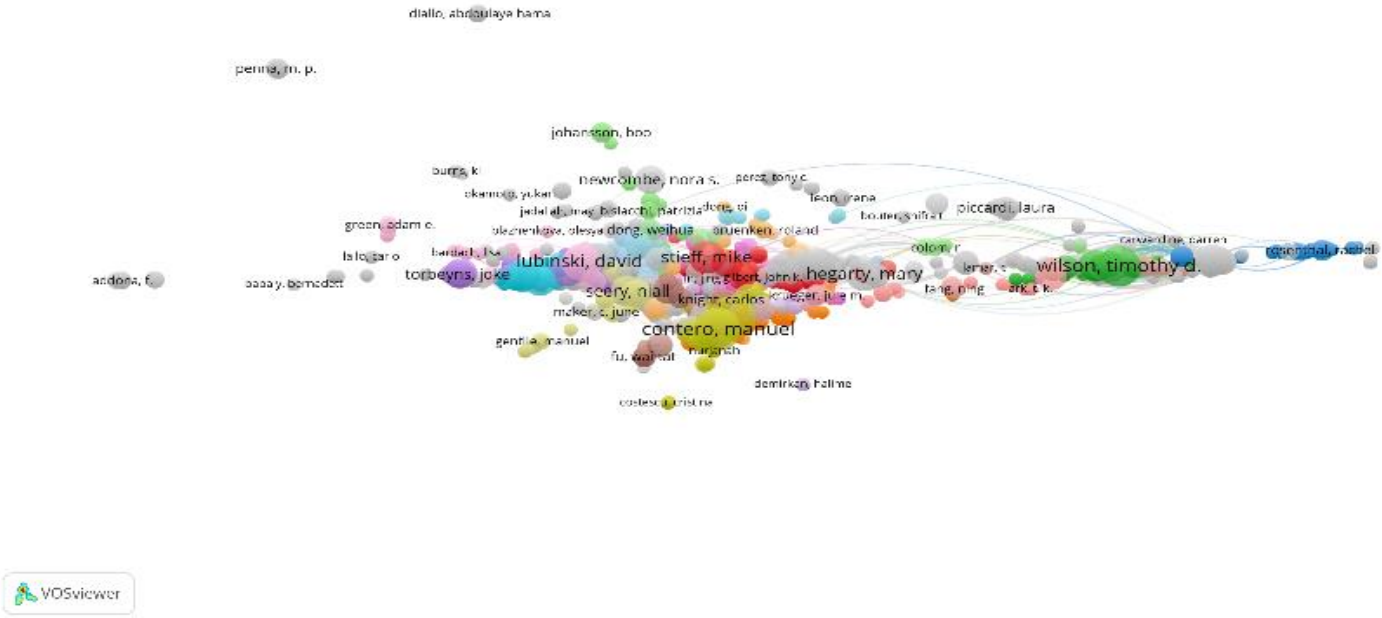

Figure 7.
Co-Citation Network of Authors

The sizes of the circles are related to the number of citations of the relevant author, and as the number of citations to the author increases, the size of the circle also increases. The links between the circles show the citation relationship between the authors. To make the image understandable and easy to read, the names of the authors have been shortened to "Surname, N". Statistical information on the link strength and the number of citations of the authors who are in a citation relationship are given in Table 4.

Table 4.
Authors with the Strongest Co-Cited Relationship (a) and Most Cited (b) (Top 10 Authors)

Author	Total link strength	Author	Citations
Zhou, X	51	Lubinski, D	1920
Contero, M	48	Mayer, RE	1426
Martin-Gutierrez, J	47	Benbow, C P	1286
Kovas, Y	45	Wai, J	886
Wilson, TD	40	Sims, VK	562
Luis Saorin, J	36	Hegarty, M	480
Roach, VA	35	Wong, KW	436
Malykh, S	34	Lee, EAL	432
Langlois, J	30	Contero, M	425
Levine, SC	29	Stieff, M	424
(a)		(b)	

When Table 4 is examined, the authors with the strongest citation relationship are Zhou, X; Contero, M; Martin-

Gutierrez, J; Kovas, Y and Wilson, TD, respectively. Among the authors with a citation relationship, the most cited authors are Lubinski, D; Mayer, RE; Benbow, CP; Wai, J and Sims, VK, respectively. It is seen that the most cited authors generally work in the subject areas of Education & Educational Research, Psychology, Computer Science and Science & Technology (Table 5).

Table 5.
Subject Areas of the Most Cited Authors

	Education & Educational Research	Psychology	Computer Science	Science & Technology	Engineering	Neurosciences & Neurology	Behavioral Sciences	Genetics & Heredity	Linguistics	Telecommunications	Imaging Science & Photographic Technology	Rehabilitation	Business & Economics	Chemistry
Lubinski, D	X	X		X			X	X						
Mayer, RE	X	X	X		X	X								
Benbow, CP	X	X		X		X	X							
Wai, J	X	X		X										
Sims, VK		X												
Hegarty, M	X	X	X			X			X					
Wong, KW	X		X		X					X	X			
Lee, EAL	X	X	X									X		
Contero, M	X		X	X	X								X	
Stieff, M	X	X	X											X

Co-citation network of scientific resources

Scientific studies on spatial ability in the field of education were published in 675 different sources (journals/symposiums). However, it was determined that 420 of these sources contain common citations. The image of the co-citation network among scientific resources is given in Figure 9.

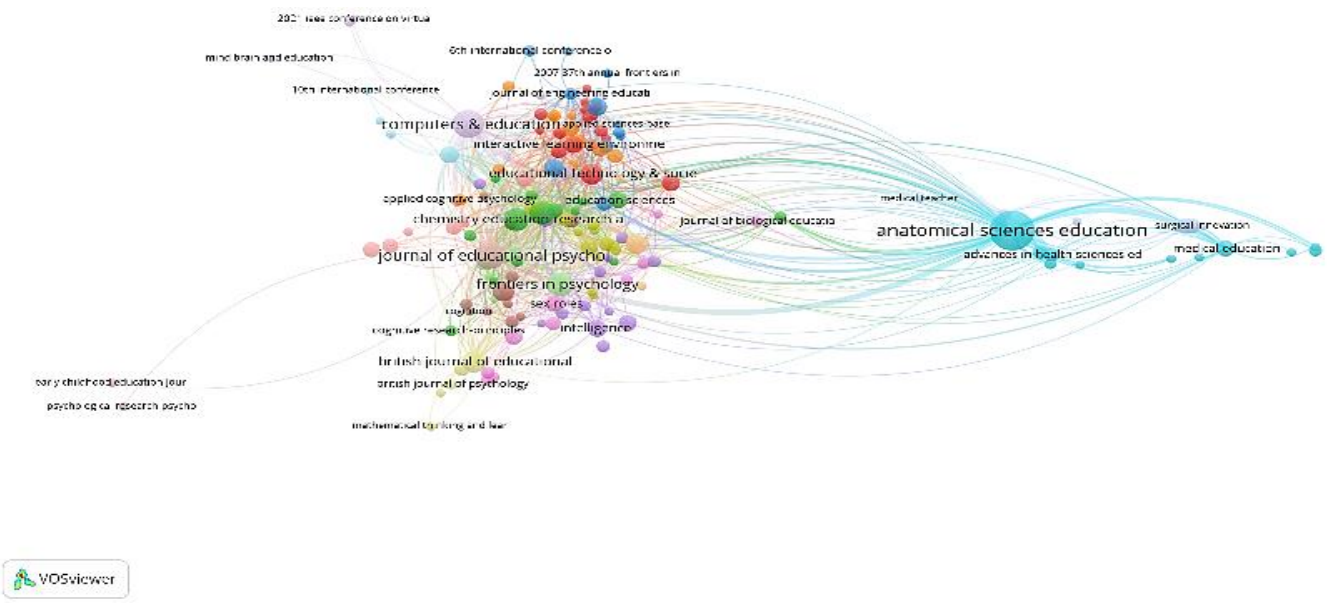

Figure 8.
Common Citation Network of Sources

The sizes of the circles in the image are related to the number of citations of the relevant source. As the number of citations to the scientific source increases, the size of the circle also increases. The lines between the circles show the citation relationship between the sources. The source names have been shortened to make the image understandable and easy to read. Statistical information on the link strength and the number of citations of scientific sources that are in a citation relationship are given in Table 6.

Table 6.
Sources with the Strongest Co-Cited Link (a) and Most Cited (b) (Top 10 Source)

Source	Total link strength	Source	Citations
Journal of Educational Psychology	535	Journal of Educational Psychology	2863
Anatomical Sciences Education	401	Anatomical Sciences Education	1591
Computers & Education	200	Computers & Education	1578
Educational Psychology Review	187	Educational Psychologist	742
Journal of Chemical Education	129	Educational Psychology Review	739
Learning and Individual Differences	114	Intelligence	556
British Journal of Educational Psychology	104	Journal of Chemical Education	512
International Journal of Science Education	98	Personality and Individual Differences	498
Chemistry Education Research and Practice	92	Computers & Graphics-UK	473
Advances in Health Sciences Education	81	British Journal of Educational Psychology	425
(a)		(b)	

When Table 6 is examined, the scientific sources with the strongest citation relationship are Journal of Educational Psychology, Anatomical Sciences Education, Computers & Education, Educational Psychology Review and Journal of Chemical Education, respectively. The most cited scientific sources are Journal of Educational Psychology, Anatomical Sciences Education, Computers & Education, Educational Psychologist and Educational Psychology Review, respectively. The index, category quartile, citation indicator and impact factor information of scientific sources are given in Table 7.

Table 7.
Journal Tag

Source	Index	Category Quartile	Citation Indicator (2021)	Impact Factor (2021/Five Year)
Journal of Educational Psychology	SSCI	Q1	2.42	6.856 / 8.608
Anatomical Sciences Education	SCIE	Q1	2.56	6.652 / 6.53
Computers & Education	SSCI	Q1	3.75	11.182 / 11.736
Educational Psychology Review	SSCI	Q1	2.31	8.24 / 11.025
Journal of Chemical Education	SCIE	Q2	1.04	3.208 / 2.988
Educational Psychologist	SSCI	Q1	1.82	8.209 / 11.302
Learning and Individual Differences	SSCI	Q1	1.21	3.897 / 3.928
Intelligence	SSCI	Q2	0.99	3.613 / 3.814
British Journal of Educational Psychology	SSCI	Q1	1.23	3.744 / 4.1
International Journal of Science Education	SSCI	Q2	1.37	2.518 / 2.776
Personality and Individual Differences	SSCI	Q2	1.09	3.95 / 4.276
Chemistry Education Research and Practice	SSCI	Q2	1.8	3.367 / 3.282
Computers & Graphics-UK	SCIE	Q3	0.86	1.821 / 1.952
Advances in Health Sciences Education	SSCI	Q1	1.44	3.629 / 4.057

Keyword Analysis

In the scientific studies conducted on spatial ability in the field of education, 2841 different keywords were identified. However, it was determined that 2645 of these keywords are in a relationship. The image of the relationship between the keywords is given in Figure 10.

The size of the circles in the image is related to the frequency of use of the relevant keyword. As the number of uses of the keyword increases, the size of the apartment also increases. The lines between the circles show the citation relationship between the keywords. For the image to be understandable and easy to read, the image of the keywords that have been used at least 10 times (N=183) is presented in Figure 11.

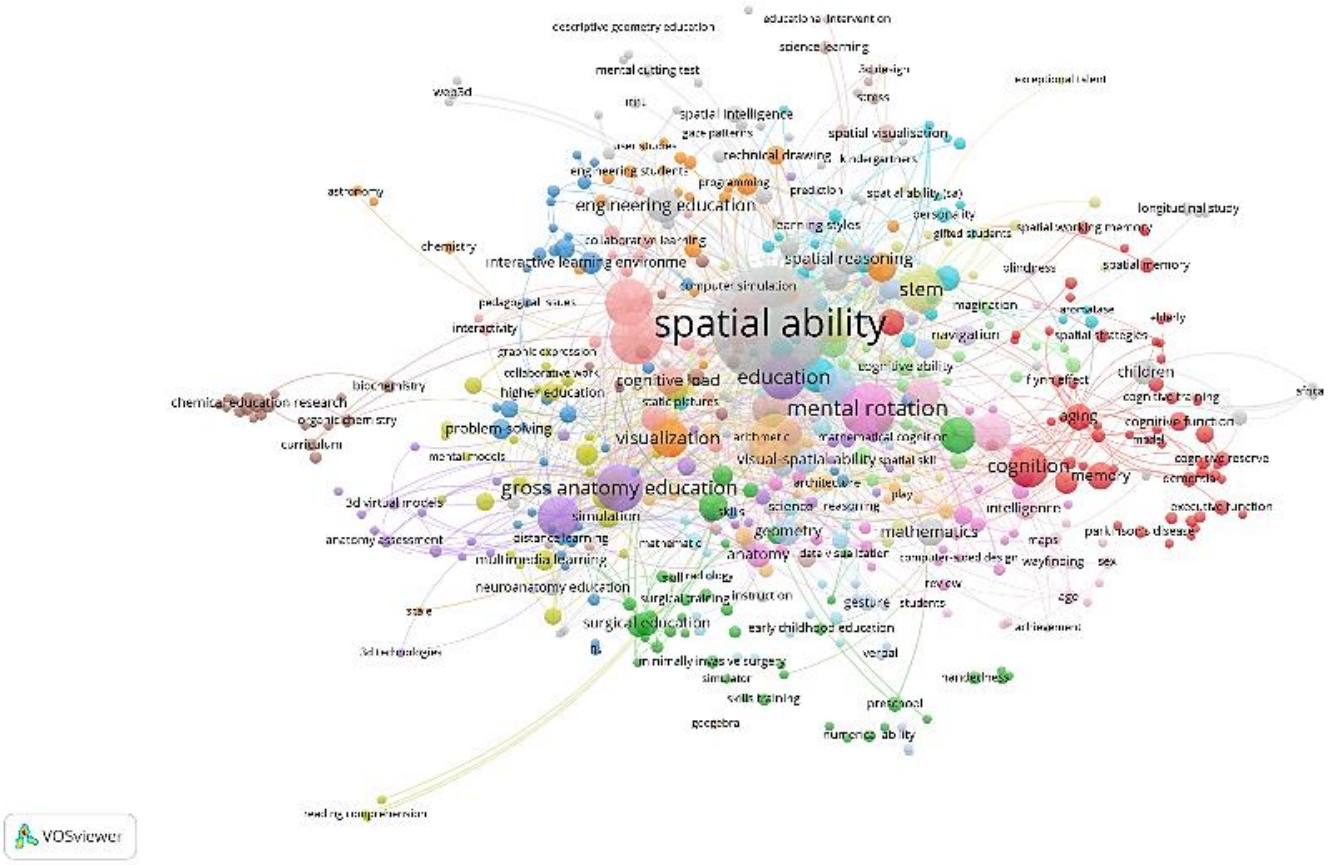

Figure 9.
Keyword Analysis

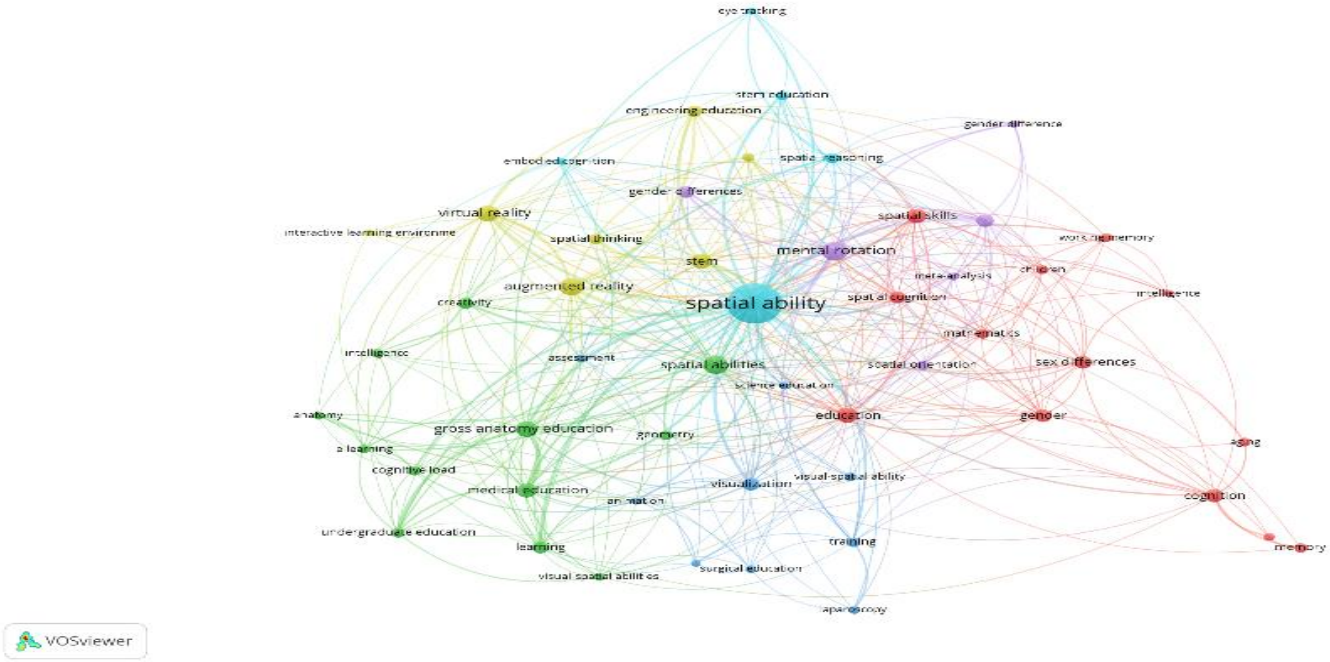

Figure 10.
Keyword Analysis (At Least 10 Occurrence)

Statistical information on the link strength and frequency of use of keywords is given in Table 8.

Table 8.

Occurency (a) and Link Strength (b) of Keywords (Top 15 Keywords)

Keyword	Occurrences	Keyword	Total link strength
Spatial Ability	288	Spatial Ability	1209
Mental Rotation	62	Gross Anatomy Education	301
Spatial Abilities	61	Mental Rotation	273
Augmented Reality	56	Spatial Abilities	271
Virtual Reality	47	Augmented Reality	232
Gross Anatomy Education	46	Education	232
Education	42	Medical Education	226
STEM	39	Virtual Reality	199
Spatial Skills	38	STEM	193
Medical Education	37	Spatial Skills	169
Cognition	34	Cognition	169
Visualization	30	Spatial Visualization	151
Sex Differences	30	Learning	147
Spatial Visualization	29	Visualization	132
Gender	28	Spatial Cognition	127
(a)		(b)	

When Figure 11 and Table 8 are evaluated together, the most frequently used keywords in spatial ability studies in the field of education are Spatial Ability, Mental Rotation, Spatial Abilities, Augmented Reality and Virtual Reality, respectively. The highest link strengths among the keywords are Spatial Ability, Gross Anatomy Education, Mental Rotation, Spatial Abilities and Augmented Reality, respectively.

Discussion

In the current study, it was aimed to examine the bibliometric characteristics of published scientific studies on spatial ability in the field of education in the WoS database. Between 1975 and 2022, there are 1317 scientific studies published in the related subject area in the WoS database. The first of these studies belongs to the year 1984. The related subject area, which gained popularity as of 2000, reached the highest number of publications in 2020.

Most of the publications in the field of education on spatial ability were made in the article type. Articles provide objective indicators for determining the academic effectiveness and scientific productivity of scientists (Karagöz & Şeref, 2019, p. 795). For this reason, it is expected that most scientific studies in literature are in the article type. In literature, it is seen that there are studies that reach similar results (Chao et al., 2007; Hernández-Torrano & Ibrayeva, 2020; Jamali et al., 2015; Jiménez-Fanjul et al. 2013; Mondal & Roy, 2018; Phan et al., 2022; Suseelan et al., 2022).

It is seen that academic publications published in English in the spatial ability literature are in the majority. English is currently the mother tongue of most people living in the United Kingdom, the USA, the Caribbean, Australia, Ireland, Canada, and New Zealand. In addition to these, it is used as a second language and official language in many countries. English stands out as the language of scientific communication in the academic world. In terms of scientific communication processes, English is one of the languages with a high level of international visibility and influence (Karagöz and Şeref, 2019, p. 796). Similar findings have been obtained in previous studies (Hernández-Torrano & Ibrayeva, 2020; Jiménez-Fanjul et al., 2013; Julius et al., 2013; Suseelan et al., 2022).

Scientific studies were produced in 82 countries related to the subject area of spatial ability. The country where the most scientific publications are made is the USA. Similar findings have been obtained in previous studies (Agbo et al., 2021; Özkaya, 2018; Jamali et al., 2015; Jiménez-Fanjul et al., 2013). The USA is followed by Spain, Canada, Germany, and England. When the cooperation between countries was evaluated, it was determined that 66 countries work in cooperation. The countries that are open to international cooperation, that is, the strongest network of relations, are respectively USA, England, Germany, Australia, and Canada. It can be said that the USA plays an important role in establishing and maintaining scientific relations between countries (Le Thi Thu et al., 2021). In terms of the number of citations to scientific studies, the countries that receive the highest number of citations are the USA, Canada, England, Spain, and Germany, respectively. As a result, it can be said that the USA is the research center for scientific studies on spatial ability in the field of education. The most publications, the most citations, and the most collaborations are in the USA.

There are a total of 1356 organizations producing scientific studies on spatial ability in the field of education. 657 of these organizations produced studies in cooperation. The organizations that produce the most scientific studies in the relevant subject area are University La Laguna (Spain), Beijing Normal University (China), Purdue University (USA), Western University (Canada) and University of Illinois (USA), respectively. When the countries where the organizations are located are examined, it is seen that the organization that produces the most publications is a university located in Spain. Organizations that attach importance to inter-organizational cooperation and produce the most work in cooperation with other organizations are respectively Tomsk State University (Russia), Beijing Normal University (China), Russian Academy of Education (Russia), University of London (England) and Harvard University (USA). Russia is not among the top 10 countries in terms of link strength. However, it is home to the organization that gives the most importance to inter-organizational work and produces the most collaborative work. The organizations receiving the most citations are Vanderbilt University (USA), University of California (USA), Northwestern University (USA), Western University (Canada) and Michigan State University (USA), respectively. When the organizations are evaluated in general, the first five organizations with the highest number of citations are in the countries that produce the most publications. Four of these organizations are in the USA. This supports our view that the USA is a research center for scientific studies on spatial ability in the field of education.

Among the 1317 scientific studies published on spatial ability in the field of education, the most cited documents are Wai et al. (2009), Mayer (1997), Mayer & Sims (1994), Wu & Shah (2004) and Cheng & Tsai (2013), respectively. Documents with the strongest citation relationship are Wai et al. (2009), Shea et al. (2001), Uttal & Cohen (2012), Guillot et al. (2007) and Lufler et al. (2012), respectively. When the authors who published in the relevant subject area are evaluated separately, the most cited authors are Lubinski, D; Mayer, RE; Benbow, CP; Wai, J and Sims, VK. In this context, it can be stated that these authors have directed literature on spatial ability in education. The authors, who attach importance to collaborative work and have the strongest link network, are Zhou, X; Contero, M; Martin-Gutierrez, J;

Kovas, Y, and Wilson TD, respectively. These authors generally produced scientific work in the subject areas of Education & Educational Research, Psychology, Computer Science and Science & Technology.

Spatial ability research in the field of education has been carried out in 675 different scientific sources (symposium, journal, etc.) and published. The most cited scientific sources are Journal of Educational Psychology, Anatomical Sciences Education, Computers & Education, Educational Psychologist and Educational Psychology Review, respectively. The scientific sources with the strongest citation link are Journal of Educational Psychology, Anatomical Sciences Education, Computers & Education, Educational Psychology Review and Journal of Chemical Education, respectively.

Finally, the most frequently used keywords in published scientific studies on spatial ability in the field of education were spatial ability, mental rotation, spatial abilities, augmented reality, virtual reality, gross anatomy education, education, STEM, spatial skills, and medical education. Among the spatial ability components in the literature, the spatial rotation component is studied more than the other components. In addition to these, it has been determined that spatial ability studies are carried out in various fields such as eye tracking [eg. Mason et al., 2013], stem education [eg. Lubinski, 2010], medical education [eg. Langlois et al., 2020], augmented reality [eg. MolinaCarmona et al., 2018], computer aided education [eg. Nurjanah et al., 2020], metacognition [eg. Ariel et al., 2018], human-robot interaction [eg. Caci et al., 2013], rehabilitation [eg. Bangirana et al., 2013], psychology [eg. Suh & Young Cho, 2020], dual-task [eg. Van Nuland & Rogers, 2015].

The findings of this study shed light on the researchers who plan to conduct a study or conduct research in the field of spatial ability. Knowing the university, organization or country that produces effective publications on spatial ability in the field of education is important for readers who want to do research on the relevant subject. Thanks to this information, researchers can have an idea about which institutions or organizations they can get support from. In this way, researchers will be able to find suitable project partners for their own projects. Similarly, it guides the readers who want to receive education on the relevant subject to which institution or organization can be applied. Researchers who plan to work in international cooperation can contact authors, countries and organizations that are more open to cooperation with the help of the current study. In this way, it is possible to easily find support for their research.

Conclusion and Recommendations

As a result of the current review, the sources that form the building block of the issue related to the determination of the documents that have been found to have received the most citations are being revealed. In this way, it is determined which sources should be examined by researchers who are curious about the starting point of the relevant subject and want to learn detailed information. Researchers who want to produce publications in the subject area of spatial ability can identify internationally influential sources for their scientific publications by examining the findings of the current study. By examining frequently used keywords, researchers can identify suitable study areas and identify areas that need research. At the same time, researchers can choose the keywords that will increase the engagement of their publications for their scientific publications by examining the keywords with the highest interaction. Thus, the visibility of the produced publication in the international literature can be increased and it can be ensured that it reaches more readers.

Etik Komite Onayı: Doküman inceleme çalışması olduğu için etik kurul izni alınmamıştır.
Hakem Değerlendirmesi: Dış bağımsız.
Yazar Katkıları: Fikir-B.Y.; Tasarım-B.Y., E.E.; Denetleme-B.Y., E.E.; Kaynaklar-B.Y.; Veri Toplanması ve/veya İşlemesi-B.Y.; Analiz ve/ veya Yorum-B.Y., E.E.; Literatür Taraması-B.Y.; Yazıyı Yazan-B.Y., E.E.; Eleştirel İnceleme-E.E.
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Genişletilmiş Özet

Amaç
Bu çalışmada, eğitim alanında uzamsal yetenek konusunda yayınlanmış bilimsel kaynakların bibliyometrik olarak incelenmesi amaçlanmıştır. Bu amaçla "Web of Science (WoS) veri tabanında taranan 'uzamsal yetenek' konulu eğitim alanındaki bilimsel yayınların demografik ve bibliyometrik özellikleri nelerdir?" araştırma sorusuna odaklanılmıştır.

Yöntem
Bu çalışma, eğitim alanında uzamsal yetenek üzerine yayınlanan ve Web of Science (WoS) veri tabanında taranan bilimsel çalışmaların incelendiği bibliyometrik bir inceleme çalışmasıdır. Veri tabanı - "spatial abil*" ve "educat*"- formülü kullanılarak taranmıştır (Erişim tarihi: 27.04.2023). 1975-2022 yılları arasında yayınlanan tüm dokümanlar bu çalışmaya dahil edilmiştir. Bu dokümanların bibliyometrik olarak analiz edilebilmesi için VOSviewer programı kullanılmıştır. Analiz sonucunda görsel bulguların yanı sıra istatistiksel bulgular (yayın sayısı, atıf sayısı, en yüksek bağlantı gücüne sahip anahtar kelimeler, yazarlar, belgeler, vb.) da elde edilmiştir.

Bulgular
İnceleme sonucunda 1317 bilimsel yayına ulaşılmıştır. Bu çalışmaların ilki 1984 yılına aittir. İlgili konu alanı 2000 yılı itibariyle popülerlik kazanarak 2020 yılında en fazla yayın sayısına ulaşmıştır. Eğitim alanında uzamsal yetenek konusunda en fazla yayın makale türünde yapılmıştır. Uzamsal yetenek literatüründe İngilizce yayınlanan akademik yayınların çoğunlukta olduğu görülmüştür. Uzamsal yetenek konu alanı ile ilgili 82 ülkede bilimsel çalışma üretilmiştir. En fazla bilimsel yayının yapıldığı ülke ABD'dir. Uluslararası iş birliğine açık, yani en güçlü ilişki ağına sahip ülkeler sırasıyla ABD, İngiltere, Almanya, Avustralya ve Kanada'dır. Bilimsel çalışmalara yapılan atıf sayısı bakımından ise en çok atıf alan ülkeler sırasıyla ABD, Kanada, İngiltere, İspanya ve Almanya'dır. Sonuç olarak ABD'nin eğitim alanında uzamsal yetenekle ilgili bilimsel çalışmalar için araştırma merkezi olduğu söylenebilir. İlgili konu alanında en çok bilimsel çalışma üreten kuruluşlar ise sırasıyla La Laguna Üniversitesi (İspanya), Pekin Pedagoji Üniversitesi (Çin), Purdue Üniversitesi (ABD), Western Üniversitesi (Kanada) ve Illinois Üniversitesi'dir (ABD). Kurumlar arası iş birliğine önem veren ve diğer kurumlarla iş birliği içinde en çok çalışma üreten kurumlar sırasıyla Tomsk Devlet Üniversitesi (Rusya), Pekin Pedagoji Üniversitesi (Çin), Rusya Eğitim Akademisi (Rusya), Londra Üniversitesi (İngiltere) ve Harvard Üniversitesi'dir (ABD). En çok atıf alan kuruluşlar ise sırasıyla Vanderbilt Üniversitesi (ABD), Kaliforniya Üniversitesi (ABD), Northwestern Üniversitesi (ABD), Western Üniversitesi (Kanada) ve Michigan Eyalet Üniversitesi (ABD) olmuştur. Eğitim alanında uzamsal yetenek üzerine yayınlanan 1317 bilimsel çalışma arasında en çok atıf alan ve en güçlü atıf ilişkisine sahip olan doküman Wai ve diğerleri (2009) tarafından yayınlanan çalışmadır. En çok atıf alan ve en güçlü atıf ilişkisi olan bilimsel kaynak ise Journal of Educational Psychology (Eğitim Psikolojisi Dergisi)'dir. Son olarak, eğitim alanında uzamsal yetenekle ilgili yayınlanan bilimsel çalışmalarda en sık kullanılan anahtar kelimeler uzamsal yetenek (spatial ability), zihinsel döndürme (mental rotation), uzamsal yetenekler (spatial abilities), artırılmış gerçeklik (augmented reality), sanal gerçeklik (virtual reality), gross anatomi eğitimi (gross anatomy education), eğitim (education), STEM, uzamsal beceriler (spatial skills) ve tıp eğitimi (medical education) olmuştur. Literatürdeki uzamsal yetenek bileşenleri arasında zihinsel döndürme bileşeni diğer bileşenlere göre daha fazla çalışılmıştır.

Sonuç ve Öneriler
Araştırma sonucunda elde edilen bulgular doğrultusunda uzamsal yetenek konu alanında araştırma yapmayı planlayan araştırmacılara ışık tutulmuştur. Uzamsal yetenek konu alanında çalışmak isteyen araştırmacılar, mevcut çalışmanın bulgularını inceleyerek bilimsel yayınları için etkili uluslararası dergileri belirleyebilirler. Araştırmacılar sık kullanılan anahtar kelimeleri inceleyerek uygun çalışma alanlarını tespit edebilir ve araştırılması gereken alanları belirleyebilirler. Araştırmacılar en yüksek etkileşime sahip anahtar kelimeleri inceleyerek bilimsel yayınları için uygun anahtar kelimeleri seçebilirler. Uzamsal yetenek alanında uluslararası iş birliklerinde çalışmayı planlayan araştırmacılar, mevcut çalışmanın da yardımıyla iş birliğine daha açık yazar, ülke ve kurumları tercih edebilirler.