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ORIGINAL ARTICLE

A Bibliometric Analysis of Systems Thinking Research in Science Education 1991–2022

Erkan Bozkurt*

Department of Social Studies Education, Faculty of Education, Uşak University, Uşak, Türkiye

***Corresponding Author:** erkan.bozkurt@usak.edu.tr

ABSTRACT

This study aimed to exhibit a bibliometric analysis of systems thinking (ST) research in the field of science education. A total of 340 articles from 201 sources indexed in the Web of Science database in the years 1991–2022 were used in the analysis. The analysis aimed to provide a review of systems thinking research in science education by identifying the dynamics of research by presenting the periodical process, current situation, and future directions. Research on systems thinking has been acknowledged to demonstrate a significant increase in recent years. Bibliometric data prove that systems thinking research concerning studies in science education exhibits a parallel increase too. This is mainly due to UNESCO's (2015) declaration of *The Education for 2030 Framework for Action*. There systems thinking was defined as a key competency among eight competencies for education for sustainable development. Correspondingly, the analysis in this study suggests that systems thinking research in science education is a lively and developing subject in the past decade.

KEY WORDS: Bibliometric analysis; chemistry education; education for sustainable development; philosophy of education; science education; systems thinking

INTRODUCTION

Two of the most important problems that are often faced in science education are that students are either not aware of the interrelationships between different fields of science or they are not conscious of the contribution of scientific thinking in solving problems that society faces (Blatti et al., 2019). In handling both problems, presenting critical thinking along with systems thinking has been stated to be effective in gaining students' understanding of more complex and real-world challenges (York et al., 2019; Sweeney and Sterman, 2000).

Today, the world population experiences many global problems such as climate change, pandemics, poverty, and economic inequalities between people, countries, and regions. To overcome these problems, it is necessary to consider sustainability in all aspects of life, including economic, social, and environmental aspects. The United Nations (UN) in 2000 declared a goal for sustainable development of the world (UN, 2000). In the following years, the United Nations Educational, Scientific and Cultural Organization (UNESCO) substantiated that goal for educational matters through the Education for Sustainable Development Program (UNESCO, 2005). In 2015, The UN's General Assembly declared 17 goals as "Sustainable Development Goals" that were planned to be active for the years 2015–2030 (UN, 2015). Moreover, UNESCO published the report "The Education 2030 Framework for Action" in 2016 to reflect the educational dimension of those goals (UNESCO, 2016). In the report, systems thinking (ST) was listed as one of the eight key competencies to accomplish the goals set by the UN and its member states. Other key competencies listed in the report were thinking skills such as anticipatory, normative, strategic, collaborative, critical thinking, self-awareness, and integrated problem-solving. From then on, the importance and necessity of ST for educational research has become evident.

ST conceives of everything in the world or more specifically in a system as somehow connected (Sterman, 2010). In this system of things or parts, an action is not an individual action, but an action that causes a chain of reactions that makes a change in the corresponding system. ST as a key competency is a thinking skill to identify and understand the characteristics of various systems, predict their behaviors, and adjust them to bring desired effects (Arnold and Wade, 2015). ST assists in understanding the whole system and finding and solving the fundamental problems of the system (Meadows, 2009).

This study aimed to provide a bibliometric analysis of ST research in science education. ST literature in science education is still being developed at the moment. It is important to present to researchers through bibliometric analysis the current situation or the state of the art and point out the future directions for research. To establish these aims, a set of research questions was devised to guide this study:

- Which publications, sources, and authors are the most efficient in ST literature in the field of science education?
- What are the trend topics, and popular subjects of ST research in science education?
- What kinds of lessons can be taken for the future of ST research in science education?

In the literature, there is only a single bibliometric study on ST (Hossain et al., 2020). In that study, the use of ST in the educational context was found to be significantly increasing in recent years (Hossain et al., 2020). However, there is no research about the science education dimension of ST research. This study by devising a bibliometric analysis aims to exhibit a general view of ST in science education and point out future research directions for the science education field. Furthermore through this study, it is expected to contribute to science education research in the context of thinking skills education.

METHODS

The bibliometric analysis is mainly used to analyze the information regarding the knowledge accumulation patterns, the most prominent authors and journals in a research field, and the most frequent words used in the published material, etc. (Pinto et al., 2019; Zupic and Čater, 2015). Furthermore, it is a popular analysis method to view trend topics and to predict future research directions in a research field. In this study, to illustrate the systematic evaluation of ST research in science education, the bibliometric analysis method was preferred.

Web of Science database of Clarivate Analytics was chosen for the search database of the published articles in ST research in science education. For the search query "system* thinking" and "education" and "science" were input in March 2023 for the topic fields which returned 471 documents. Afterward, the following refinement criteria were applied: Publication years = All years except for early access (1991–2022); Document type = Article; Language = English. As a result, the Web of Science database returned 340 documents from 201 sources. The analysis tools for the bibliometric analysis are the RStudio, the Biblioshiny web app (version 4.1.2), and the VOSviewer software (version 1.6.19).

Bibliometric analysis in this study was conducted through two main techniques. First is the performance analysis which examines the contributions of research components to a particular field, and the other is the science mapping analysis which focuses on the relationships between research items (Donthu et al., 2021). Figure 1 illustrates both the techniques used and the software tools used for the analysis.

FINDINGS

General Characteristics of the Literature

ST research in science education exhibits general characteristics that are listed in Table 1. In the Web of Science database, a total of 340 documents were identified after setting appropriate search criteria.

The annual growth rate of the publications in the search dataset was found to be 10.8 which signifies that the research field is lively and growing each year. The average citation count for the documents was 17.57 which indicate that documents in the dataset are well cited by other researchers in the research field. The average age of the documents in the dataset was 6.54 which implies that the research field is still in the development stage and that the publications in the field are relatively new.

Annual Scientific Production

The annual scientific production of ST research in science education started to increase significantly from the beginning of the millennium (Figure 2). Although this increase is sometimes remittent, from the year 2015 as mentioned in the introduction UNESCO has declared "The Education 2030 Framework for Action" (UNESCO, 2016). From that year, ST as a key competency to pursue education for sustainable development became an important theme for science education research.

Another upheaval in ST research occurred in the year of 2019. When the articles in that year are analyzed it is observed that studies concerning chemistry education became prominent. This is mainly due to the Systems Thinking in Chemistry (STICE) project established by the International Union of Pure and Applied Chemistry (IUPAC) (Mahaffy *et al*., 2019a). As part of the project, a special edition of the *Journal of Chemical Education* was published in December 2019 with many studies authored about ST in the context of chemical education. This

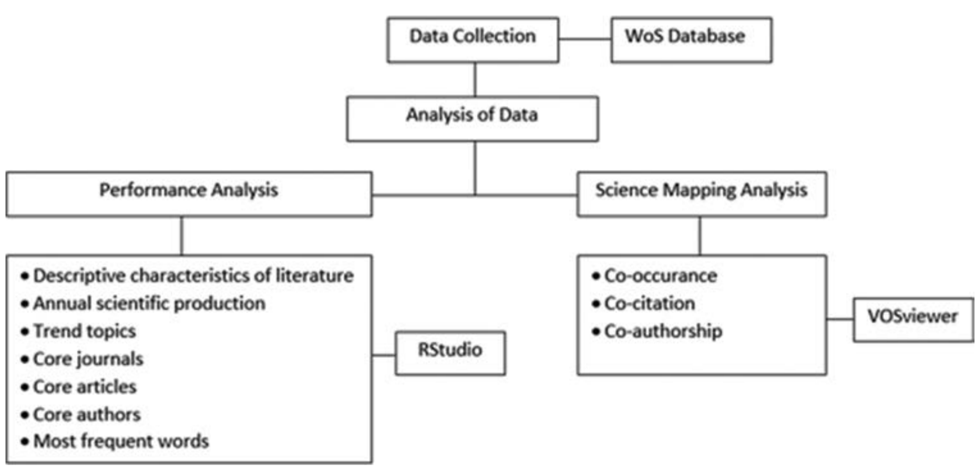

Figure 1: The process of bibliometric analysis

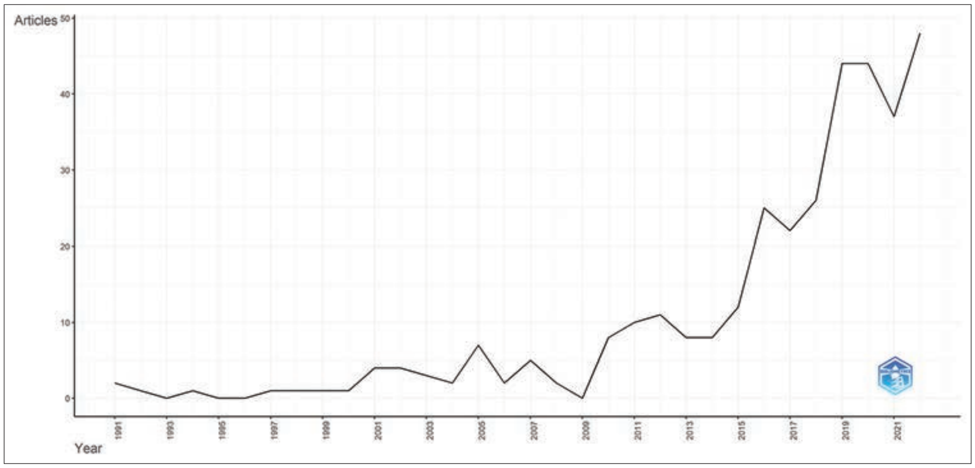

Figure 2: Annual scientific production of ST research in science education

Table 1: Descriptive characteristics of the literature on ST research in education

Description	Results
Main information about data	1991:2022
Timespan	
Sources (Journals, Books, etc.)	194
Documents	340
Annual Growth Rate %	10.8
Document Average Age	6.54
Average citations per doc	17.57
References	15,672
Document Types	
Article	340
Document Contents	
Keywords Plus (ID)	643
Author's Keywords (DE)	1,071
Authors	
Authors	1,021
Authors of single-authored docs	54
Authors Collaboration	
Single-authored docs	57
Co-authors per Doc	3.31
International co-authorships %	20.59

project and its traces are still effective in ST research in both chemistry education and science education in general.

Trend Topics

Among 1,070 authors' keywords from the 340 documents, the most used keywords from 1991 to 2022 are shown in Figure 3. In the figure, the horizontal lines display the evolutionary process of the corresponding keyword and the blue dots on the line represent the median year of the articles published with the corresponding keyword. Moreover, the dots' size on each line indicates the frequency or the number of times the keywords are used in the articles published in the corresponding year.

In the analysis, the longest duration for the keywords was observed for the keywords of complexity, competencies, and system dynamics. Science education, engineering education, and environmental education are found to be the key subjects in the research field. In the last years, science education, stem (science, technology, engineering, and mathematics education), and chemistry education appear to be the trend topics in the area.

Influential Aspects of ST in Science Education Literature

Core journals

Source impact and Bradford's law analyses were used to find the core journals of the research field. Bradford's law defines the distribution of articles in the most influential journals (Garfield, 1980). Table 2 lists the top ten journals of ST research in science education based on the h-index of the articles published in the corresponding journals. Besides h-indexes, g-, and m- indexes, total citation counts (TC), number of publications (NP), and publication starting year (PY-Start) are also displayed in Table 2.

Journal of Chemical Education has the highest h-index among the most influential sources in ST research in science education. This is mainly due to the recent attraction of educational researchers to the ST in chemistry education. The g-index indicates the citation performance of the most read articles. According to the g-index, the *Journal of Chemical Education* has again the highest score. Both the *International Journal of Science Education* and the *Journal of Research in Science Teaching* have high scores in the h- and g- indexes. The m-index on the table is calculated by dividing the h-index by the total years the journal is active. *Journal of Chemical Education* has again the highest score concerning the m-index. The total citation (TC) scores of each journal also signify how influential the articles published in the corresponding journals are. *Journal of Research in Science Teaching* has the most TC among the most influential journals in ST research in science education. Although *Journal of Chemical Education* ranks first in other indexes, in TC number, it follows behind *Journal of Research in Science Teaching*. Nevertheless, it can be said that concerning h-, g-, and m-indexes the most effective

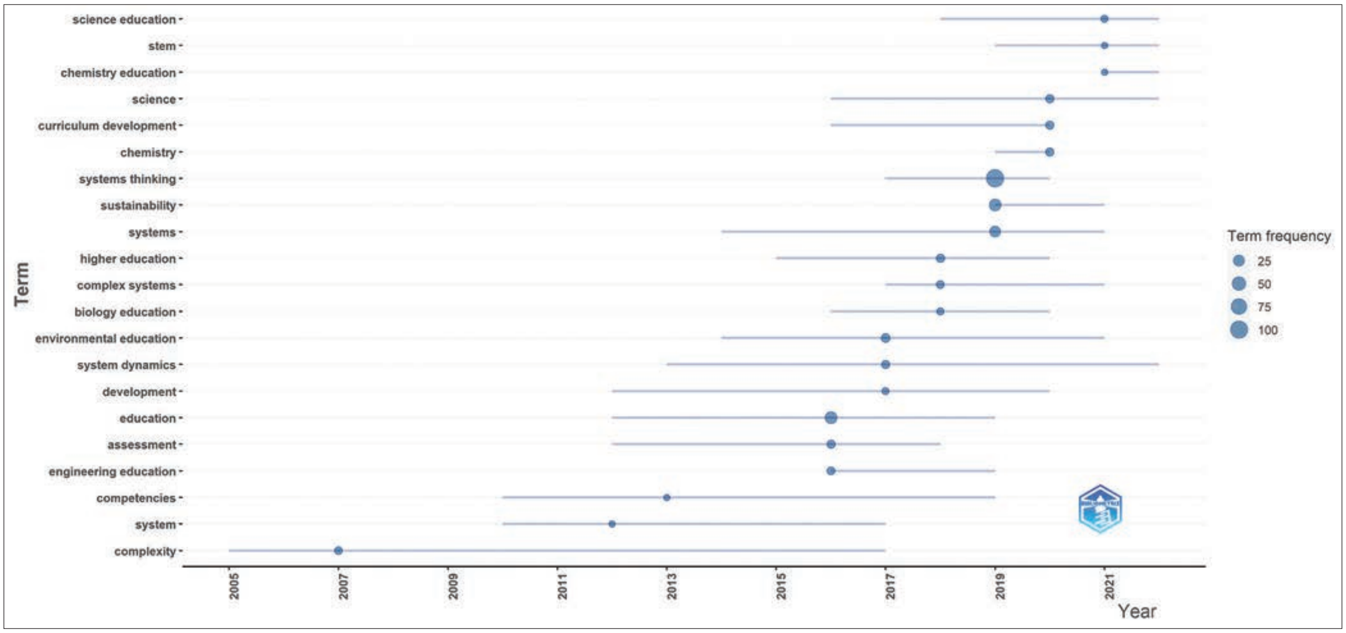

Figure 3: Trend topics analysis based on Author's Keywords in Biblioshiny©

Table 2: Top ten journals according to source impact

Journals	h-index	g-index	m-index	TC	NP	PY-start
Journal of Chemical Education	13	21	1.857	490	29	2017
International Journal of Science Education	9	14	0.391	317	14	2001
Journal of Research in Science Teaching	8	10	0.381	697	10	2003
Academic Medicine	7	8	0.219	229	8	1992
International Journal of Sustainability in Higher Education	5	5	0.625	88	5	2016
Journal of Cleaner Production	4	4	0.364	161	4	2013
Research in Science Education	4	6	0.222	62	6	2006
Systems	4	4	0.400	35	4	2014
Systems Research and Behavioral Science	4	6	0.174	102	6	2001
Chemistry Education Research and Practice	3	3	0.600	20	3	2019

journal in ST studies in science education research is the *Journal of Chemical Education.*

Journal rankings according to Bradford's law are listed in Table 3. Each source's publication frequency in ST research in science education is ordered from the highest to the lowest. Furthermore, the journals in the research field are categorized into three zones. Journals in the first zone are called the most influential sources in Bradford's law analysis. Table 3 lists the most influential journals according to this analysis.

Core articles

The most influential core articles in ST research in science education are the most cited by other studies. There are two aspects of citation counts. First is the total number of publications in the entire Web of Science database that cited the corresponding article which is called the Global Citation Score (GCS). Second is the total number of citations that an article received among the sample space of ST research in science education which is called the Local Citation Score (LCS). The top ten articles according to LCS and GCS are listed in Table 4.

The top three studies by Ben-Zvi Assaraf and Nir Orion have the highest GCS and LCS among the core articles (Ben-Zvi Assaraf and Orion, 2005; Ben-Zvi Assaraf and Orion, 2010a; Ben-Zvi Assaraf and Orion, 2010b). All three studies by these authors have the same subject which is the water cycle in the context of earth system education. However, the sample population in the first and the third study is junior high school students, but in the second one, the sample population is elementary school students. These articles became especially important for science education research, such as biology education, chemistry education, and stem education.

The fourth most cited article by local citation scores is by Riess and Christoph Mischo (2010), which is titled "Promoting Systems Thinking Through Biology Lessons." This article evaluates different approaches for promoting ST in science education within the context of biology lessons. Although the authors preferred biology lessons as the context of evaluation, their main concern is general science education.

The first four articles in the top ten articles listed in Table 4 have been published in the past 10–15 years. Publications that were

Table 3: Journal ranking according to Bradford's law

Journals	Rank	Freq	cumFreq	Zone
Journal of Chemical Education	1	29	29	Zone 1
International Journal of Science Education	2	14	43	Zone 1
Journal of Research in Science Teaching	3	10	53	Zone 1
Academic Medicine	4	8	61	Zone 1
Sustainability	5	8	69	Zone 1
Journal of Science Education and Technology	6	6	75	Zone 1
Research in Science Education	7	6	81	Zone 1
Systems Research and Behavioral Science	8	6	87	Zone 1
Education Sciences	9	5	92	Zone 1
International Journal of Sustainability in Higher Education	10	5	97	Zone 1
Instructional Science	11	4	101	Zone 1
Journal of Cleaner Production	12	4	105	Zone 1
Journal of Public Health and Management and Practice	13	4	109	Zone 1
Kybernetes	14	4	113	Zone 1

Table 4: Local citation score (LCS) and global citation score (GCS) of the publications

Article	Author	Source	Year	LCS	GCS
Development of System Thinking Skills in the Context of Earth System Education	Orit Ben-Zvi Assaraf, Nir Orion	Journal of Research in Science Teaching	2005	64	275
System Thinking Skills at the Elementary School Level	Orit Ben-Zvi Assaraf, Nir Orion	Journal of Research in Science Teaching	2010a	24	91
Four Case Studies, 6 Years Later: Developing System Thinking Skills in Junior High School and Sustaining Them Over Time	Orit Ben-Zvi Assaraf, Nir Orion	Journal of Research in Science Teaching	2010b	19	66
Promoting Systems Thinking through Biology Lessons	Riess, Christoph Mischo	International Journal of Science Education	2010	18	87
Applications of Systems Thinking in STEM Education	Sarah York, Rea Lavi, Yehudit Judy Dori MaryKay Orgill	Journal of Chemical Education	2019	15	51
Effect of Knowledge Integration Activities on Students' Perception of the Earth's Crust as a Cyclic System	Yael Kali, Nir Orion, Bat-Sheva Eylon	Journal of Research in Science Teaching	2003	14	76
Integrating the Molecular Basis of Sustainability into General Chemistry through Systems Thinking	Peter G. Mahaffy, Stephen A. Matlin, J. Marc Whalen, and Thomas A. Holme	Journal of Chemical Education	2019	14	39
Understanding the Earth Systems: Expressions of Dynamic and Cyclic Thinking Among University Students	Or Bartzri, Orit Ben Zvi Assaraf, Carmit Cohen, and Nir Orion	Journal of Science Education and Technology	2015	13	25
Graphical Tools for Conceptualizing Systems Thinking in Chemistry Education	Katherine B. Aubrecht, Yehudit Judy Dori, Thomas A. Holme, Rea Lavi, Stephen A. Matlin, MaryKay Orgill, and Heather Skaza-Acosta	Journal of Chemical Education	2019	13	24
Systems Thinking in Chemistry Education: Theoretical Challenges and Opportunities	Samuel Pazicni, Alison B. Flynn	Journal of Chemical Education	2019	11	24

published in the most influential journals like the *Journal of Chemical Education* which are related to chemistry education are relatively new. Shortly, those articles may most probably receive more citations from studies in science education.

Core authors

Core or the most influential authors in ST research in science education concerning their h-indexes can be found in Table 5. Each author's g-index and m-index values are given in the table with the total citations their studies received from others' studies. The number of publications of each author in the Web of Science database with the initial year they published their studies is also given in Table 5.

According to the results, Yehudit Judy Dori appears to be the most influential author with the highest h-index and g-index. Dori also receives a total of 309 citations from other studies in nine publications she has published in the field. Ben-Zvi Assaraf and Orion also appear to be the most cited authors with their articles mentioned in the core articles section above.

According to the m-index, MaryKay Orgill appears to be the first on the list which proves that Orgill contributed much to ST research in science education in a short period.

Most frequent words

The most frequently used words in ST research in science education are listed in Table 6. The table is divided into four parts Keywords Plus, Author's Keywords, Title, and Abstract. In each part, the most used words or word phrases by the authors of the articles are listed. In Keywords Plus, "science," "education," and "knowledge" appear to be the most three words. "Systems Thinking" lags at the eighth row of the list. However, in Author's Keyword, Title, and Abstract, "systems thinking" is the first frequent word used in all the publications in the research field of interest. "Thinking skills," "chemistry education," "sustainability," and "sustainable development" appear to be the most frequent words in articles of ST in science education research. Besides these, words related to medicine such as, "public health," "health care," and "medical education" are also noticed in the table.

Table 5: Top ten authors in ST research in science education

Authors	h-index	g-index	m-index	TC	NP	PY-start
Dori	7	9	0.304	309	9	2001
Gonzalo	6	6	0.857	171	9	2017
Zoller	6	5	0.261	175	6	2001
Ben-Zvi Assaraf	5	5	0.263	437	5	2005
Orgill	5	7	1.000	194	5	2019
Orion	5	4	0.238	535	7	2003
Lavi	4	6	0.800	83	4	2019
Wolpaw	4	5	0.571	63	6	2017
York	4	4	0.800	170	4	2019
Dori	3	3	0.750	19	3	2020

Conceptual Structure

Co-occurrence network

Co-occurrence network analysis of the author's keywords has been extensively used in bibliometric analyses to analyze the main research topics and determine the hot topics for future research (Mao et al., 2020). Which keywords occur together in research texts of the field signify the research clusters of a particular research field (Radhakrishnan et al., 2017; Ferreira and Robertson, 2020). Keywords that occur together in a text are connected by links in the graph as shown in Figure 4. When the corresponding keywords occur multiple times in the articles then the link strengths increase. If the frequency of a keyword in a research text increases, it is shown in the figure by the node size of the corresponding keyword. Keywords that occur together more form a cluster which signifies that they are categorized into the same research cluster.

In the co-occurrence, analysis executed by the VOSviewer© software the minimum number of occurrences of a keyword was set to 2. 174 keywords of the 1,050 keywords are displayed in the network indicating 809 links with total link strength of 1,262, and they are divided into 13 clusters.

Table 6: Most frequent words

Keywords plus		Author's keyword	
Words	Occurrences	Words	Occurrences
Science	116	Systems Thinking	108
Education	80	Sustainability	33
Knowledge	31	Education	31
Students	30	Systems	24
Skills	28	Thinking	19
Complex-Systems	24	Curriculum	18
Framework	19	Learning	13
Systems Thinking	19	Environmental Education	11
Thinking	19	First-Year Undergraduate/General	11
Context	17	Green Chemistry	9
Title		**Abstract**	
Words	**Occurrences**	**Words**	**Occurrences**
Systems Thinking	91	Systems Thinking	531
Thinking Skills	12	Thinking Skills	64
Chemistry Education	11	Chemistry Education	58
Sustainable Development	10	Public Health	53
System Thinking	9	Science Education	49
Medical Education	8	System Thinking	48
Systems Science	8	Sustainable Development	44
Complex Systems	6	Complex Systems	35
Health Systems	6	Health Care	26
Public Health	6	Systemic Thinking	26

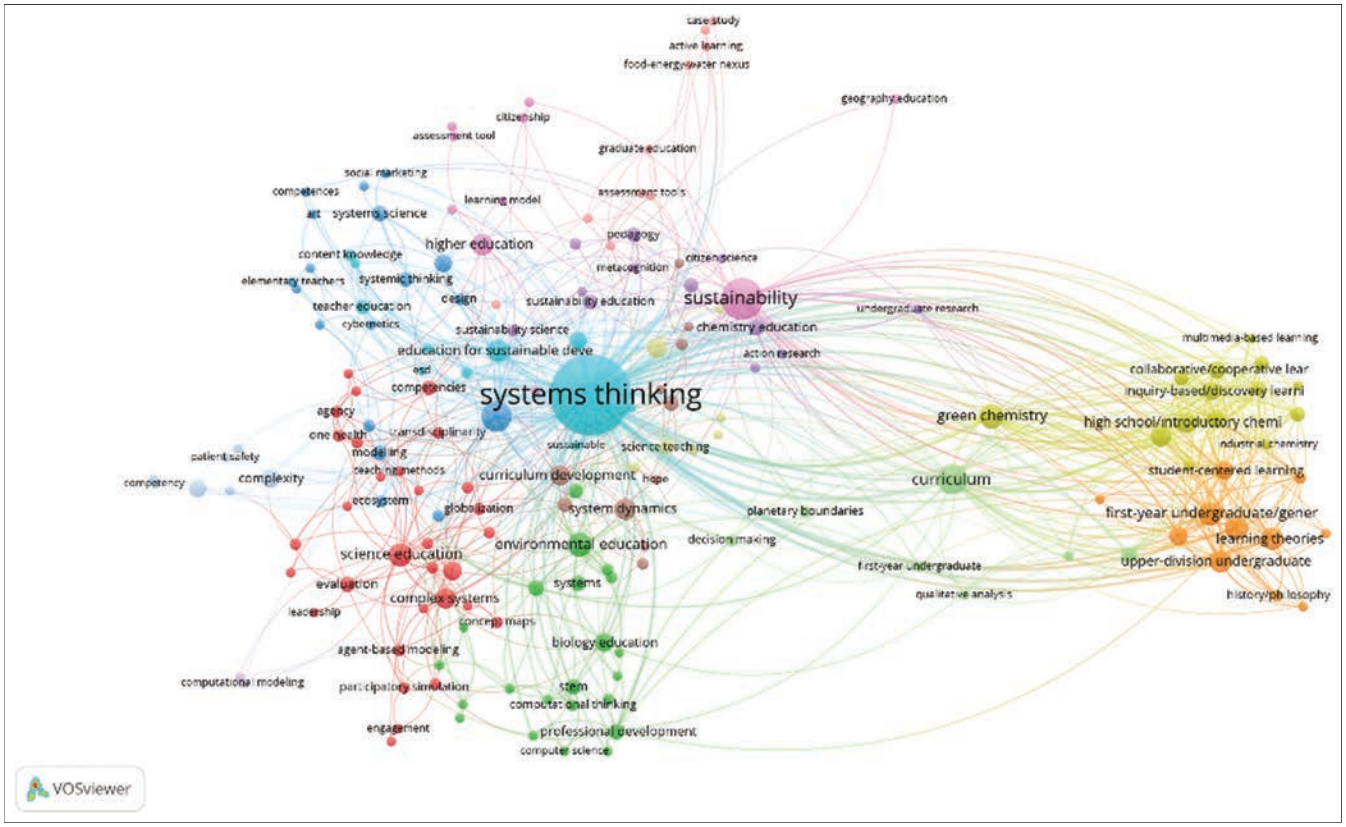

Figure 4: Co-occurrence network of author's keywords

According to the co-occurrence network analysis, the most frequently used keyword is "systems thinking." Related keywords with ST, such as sustainability, curriculum, education, green chemistry, environmental education, and science education also found to be among the frequently used keywords in ST research in science education. When viewed in the context of clusters, a cluster where "systems thinking" is dominant also resides the words such as food energy, water nexus, critical zone, creativity, and object-process methodology. The cluster where "sustainability" belongs has also related words such as higher-order thinking, higher education, educational technology, and citizenship. Other keywords such as, applications of chemistry, environmental chemistry, industrial chemistry, and polymer chemistry form a cluster with green chemistry being a cluster of chemistry-related keywords. In these studies, learning techniques that are related to chemistry education such as collaborative/corporative learning, hands-on learning, manipulatives, and internet-based/multimedia-based learning are observed to be prominently used by chemistry educationalists. When we examined the keywords related to environmental education, studies related to K-12 education comes to the front. In general, it was observed that ST was employed in many areas of science education such as medical education, biology education, chemical education, and stem.

Co-authorship analysis

Scientific collaboration among researchers is an important metric to understand the complexity and the scope of the research field. As the specialization of the research fields becomes broader and deeper as time passes, the importance to bring together different skills and knowledge together makes scientific collaboration from every perspective becomes a necessity (Katz and Martin, 1997; Sonnenwald, 2007). When researchers share common meanings and fulfillment of tasks to accomplish shared goals, scientific collaboration occurs (Sonnenwald, 2007). Scientific collaboration promotes research in unpredicted directions by boarding the scope of the research that the researchers can conduct (Beaver, 2001).

When the co-authorship analysis in VOSviewer© was performed then the resulting collaboration map shown in Figure 5 illustrates the scientific collaboration in ST research in science education. From the collaboration map, it is seen that the researchers do not form an interconnected network and their groups are rather isolated which indicates that there is no single group or person that leads the ST research in science education.

Co-citation analysis

Co-citation analysis is a science mapping technique to display the intellectual background of the research field. In the study, VOSviewer© software was utilized to observe the co-citation analysis of ST research in science education. For the analysis minimum threshold level for the number of citations a cited document receives is set to 10. 62 documents out of the total of 16,373 documents satisfy this condition.

Figure 5: Co-authorship analysis of ST research in education.

The network map of the co-citation analysis is shown in Figure 6. In the map, the node and label sizes of the items indicate the importance of the corresponding research article for the field. Authors that are more likely to be cited together in a given document are mapped together in the same cluster. Connections between the documents are formed by links and the documents that have more connections when compared to other documents form a cluster in the network map. Each item in the map belongs to a single cluster. Each cluster has a distinct color and every document has the color of the cluster it belongs to. The degree of co-citation between documents is determined by the sizes of the clusters. If there are strong connections between the documents, then it is indicated by the width of the connection lines.

As seen in Figure 6, four main clusters in the co-citation analysis of ST research in education are evident. The article by Ben-Zvi Assaraf and Orion (2005a) titled "Development of Systems Thinking Skills in the Context of Earth System Education" leads the first cluster (colored red) by receiving the most citations. Besides this study, articles by science educationalists such as Jacobson (2001), Wilensky and Reisman (2006), and Hmelo-Silver et al. (2017) and by management scientists such as Sweeney and Sterman (2007) also come to the front in the first cluster.

In the second (green-colored) cluster, an article by Orgill et al. (2019) which is about employing ST in chemistry education comes to the front. In chemistry education, works by authors such as Matlin et al. (2015), Mahaffy et al. (2019a, 2019b), and York et al. (2019) also take place in this cluster. In this cluster, works on sustainability research also take place. Articles authored by sustainability researchers such as Wiek et al. (2011), and Steffen et al. (2015) come to the front in this cluster. Furthermore, studies in engineering and stem research by Arnold and Wade (2105), Grohs et al. (2018), and Sabelli (2009) take place in the second cluster. Meadows' work (2009) which is on environmental science belongs to the mentioned cluster.

In the third (blue-colored) cluster, an article authored by Evagorou et al. (2009) which is a simulation about developing ST in elementary schools comes to the front. Furthermore in this cluster, a study by Sweeney and Sterman (2000) which is about bathtub dynamics; a study by Boersma et al. (2011) on ST in biology education takes place. Hung's article (2008) about enhancing ST skills with modeling and Riess and Mischo's article (2010) on ST applications in biology education and the study by Brandstädter et al. (2012) which is about employing ST in concept-mapping practices also belong to this cluster.

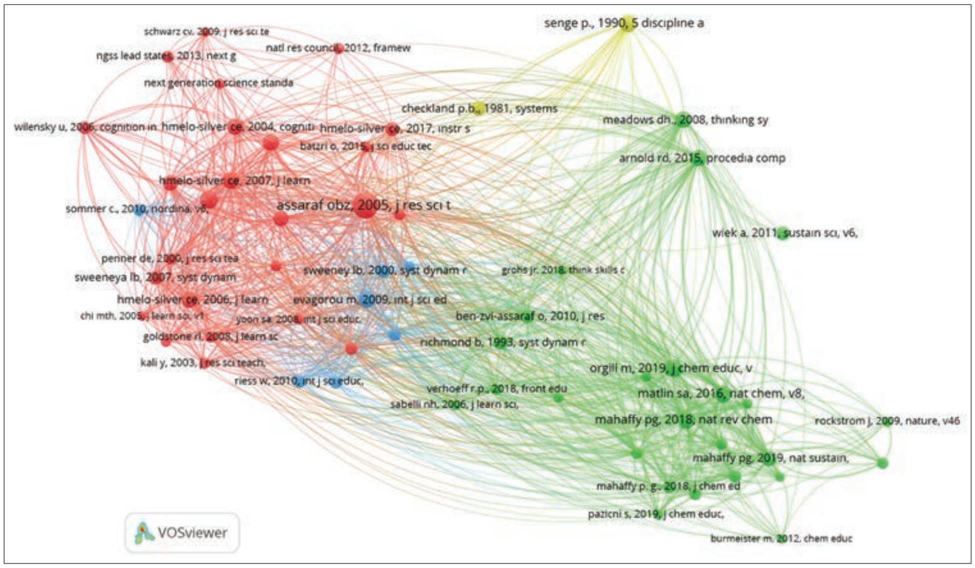

Figure 6: Co-citation analysis of references

Finally, Sommer and Lucken's work (2010) in this cluster, surveys applications of ST in science education, especially in elementary schools.

The fourth (yellow-colored), and last cluster on the map consists of foundational publications in ST, such as Peter Senge's book (1994) titled *The fifth discipline: The art and practice of the learning organization* which was published in the 90s, and Peter Checkland's book (1981) titled *Systems Thinking, Systems Practice* which was published in the 80s.

DISCUSSION AND CONCLUSION

From the bibliometric analysis, it is evident that ST research in science education has become more prominent since the beginning of the millennium. However, yearly publications in the research field accelerated after the declaration of UNESCO's "The Education 2030 Framework for Action" report (UNESCO, 2016). ST in that report was set as a key competency for the education for sustainable development. In research on chemistry education, a special interest in ST has been observed from the year of 2019. As mentioned before, this is mainly due to the special edition of the *International Journal of Chemical Education* on ST research in chemistry education. This special edition was configured by the project of IUPAC (International Union of Pure and Applied Chemistry) titled STICE (Systems Thinking in Chemistry Education). This special focus of research on chemistry education about ST is an important point of discussion.

Chemistry education which is interconnected to other scientific disciplines such as physics, biology, and earth sciences, is seen as a "central science" for sustainability (Mahaffy et al., 2019b, Holme and Hutchison, 2018). In the Anthropocene epoch, the problems faced by nature could be solved by individuals that are equipped with thinking skills such as systems thinking and creative thinking. Contemporary chemistry teaching is attempting to infuse systems thinking into the science curricula, to adapt creative thinking as part of the scientific method, and to emphasize interdisciplinary problem-solving. This fact has also been observed in the co-occurrence analysis above when techniques of learning come to the front as research keywords in the published articles. To solve the global problems of the Anthropocene epoch, various learning techniques become prominent in chemistry education to acquire systems thinking competency. This is especially crucial for education for sustainable development.

In science education, the systems thinking approach has the potential to bring forward real-life subjects into the classroom, such as ecology, earth systems, biology, stem, agriculture, health sciences, engineering, and management. This enhances learning and conceiving corresponding subjects and paves the way for a better handling of the world as a whole. Since science and its technological output have the most hazardous effects on the environment, it is important to conceive scientific activity as part of the world system. To achieve a sustainable future, systems thinking should be a central part of education. Thus, systems thinking is an important thinking skill to be integrated especially into the science education curriculum. The bibliometric analysis in this study displays collateral findings with this evaluation.

Ethical Statement

Since this study is based on the previously published data which is also publicly available, no ethical approval was required.

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