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Studies on scientific literacy in primary education: A bibliometric and content analyses

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RESEARCH ARTICLE

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ABSTRACT

This study aims to ascertain the research trends of articles on scientific literacy in primary schools. In the study, both bibliometric and content analysis techniques were employed. In the Web of Science database, 145 studies conducted between 1993 and 2021 and 60 studies conducted between 2002 and 2021 were included in the content analysis for bibliometric analysis. According to the findings, there is a rising interest in scientific literacy in primary schools. Bybee, R., and McCrae, B., were the most cited authors in this study. The United States was the most frequently cited country, and the Australian Council for Educational Research was the most frequently cited institution. Few mixed studies have been conducted on the topic of scientific literacy, as qualitative studies have dominated the field. As sample groups, primary school students and college graduates were favored. The study concluded that scientific literacy in primary school is mostly promoted by organizations, journals or authors in developed countries. The results of the study were discussed in light of the relevant literature, and suggestions for further studies were offered.

KEYWORDS

scientific literacy, primary school, bibliometric analyses, content analysis

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INTRODUCTION

Science plays a crucial role in today's and tomorrow's society, including the technologies and products that facilitate human life and labor. Today, international education emphasizes the significance of literacy (Udompong & Wongwanich, 2014). At the end of the 20th century, the Organization for Economic Co-operation and Development (OECD), the United States of America, and the European Union initiated research to identify the essential 21st-century competencies of future individuals in order to meet the demands of the global age (Yao & Guo, 2018). Significantly, future generations should develop scientific skills and the capacity to solve global problems resulting from limited scientific thought in order to ensure sustainability (Jimenez & Menendez Alvarez-Hevia, 2021).

Recent studies in STEM have revealed the importance of scientific literacy (SL). PISA surveys administered by the OECD, one of the international organizations, are also prominent in SL. Literate individuals play an active role in reducing global problems and promoting sustainable development, according to UNESCO. Roberts (2007) states that policymakers and STEM educators have advocated for the SL since the 1950s. In this regard, it holds a unique position among 21st century skills. This understanding is the foundation of SL (Kaya, Bahceci, & Altuk, 2012; Khusniyawati & Suryanti, 2018; Krell, Koska, Penning, & Kruger, 2015). Contemporary science education places a heavy emphasis on SL, and it is an essential component of national curricula in a number of countries, thereby contributing to the acceleration of the globalization of science education (Wang, Lavonen, & Tirri, 2019).

Programs should be designed to enable students to acquire SL, one of the skills of the 21st century. For this reason, literacy skills are included in the science course objectives of the curricula of many countries (Association for the Advancement of Science, 1990; National Research Council, 2012). To develop scientifically literate students, inquiry and inquiry-based learning methods are preferred. Thus, students can engage in authentic learning through practice-based scientific discovery (NRC, 2012).

WHAT IS SCIENTIFIC LITERACY?

In the 1950s, scientific literacy (SL) was first introduced. In 1983, a report published by the "National Commission on Excellence in Education" (Demirel & Caymaz, 2015) began to garner SL interest in the United States. Since its inception, it has been used with a variety of different meanings (Bybee, 2015). Literacy is the ability to use the skills necessary to function in a society, whereas SL refers to scientific competence (Harlen & Qualter, 2004; Sjostrom & Eilks, 2018; Smith, Loughran, Berry, & Dimitrakopoulos, 2012; Vrana, 2018). It is a broad concept that includes scientific reasoning, creative idea generation, and problem-solving skills.

Since SL can emerge in different cultural contexts and the individual's culture influences his or her view of nature and learning style, its definition requires extensive consideration (Seraphin, 2014). Since the meaning/definition of SL varies by country and over time, it is extremely challenging to create universal or widely accepted definitions. OECD (2020) defines it as the capacity to engage with science-related issues and ideas in order to solve every day scientific problems as a reflective citizen. Scientific literacy is the ability to explain scientific facts, design scientific research, interpret data and scientific evidence, and apply scientific knowledge to real-

world situations. According to the National Academy of Sciences (NAS), it is the ability to make decisions and participate in society, culture, and the economy using scientific knowledge, scientific concepts, and scientific processes (NAS, 2016). The NRC defines scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in social and cultural relationships, and economic productivity" (NRC, 2012, p. 3). It is accepted that individuals who comprehend fundamental scientific concepts and keep up with scientific developments possess SL (Miller, 2010). According to PISA, "scientific literacy" refers to the ability of a citizen to engage critically with scientific concepts and challenges (OECD, 2017). Harlen and Qualter (2018) reported that a scientifically literate individual has the following three basic characteristics.

- capable of functioning confidently about scientific aspects of the surrounding environment.
- able to determine something scientifically.
- able to assign values to scientific knowledge and its production.

THE STRUCTURE OF SCIENTIFIC LITERACY

For years, scientists have been studying the components and definitions of SL. Norris and Phillips (2003) distinguished between the fundamental meaning of SL (i.e., the ability to comprehend scientific arguments and recognize their strengths and weaknesses) and its derivational meaning (knowledge of, education, and learning). Its concepts are derived from literary meaning rather than being explained in a literal sense. According to Osborne (2007), SL is an essential component of the education of future scientists, as stated by the PISA program. Roberts (2007, 2011) discusses SL in relation to two visions constituting the continuum of scientific understanding. Vision I emphasizes scientific methods and content. Vision II differs in its socio-scientific methodology. It emphasizes understanding the relevance of scientific knowledge to daily life and society. It demonstrates the necessity of learning science due to understanding and acquiring knowledge of the situations students will encounter daily (Smith et al., 2012). It emphasizes the importance of applying literacy skills to scientific issues.

Hodson (2011) defined a new dimension of SL as critical scientific literacy and described this dimension as the aspect of Vision II with a greater emphasis on critical thinking. He also emphasized the critical aspect of SL by stating that scientific literacy that focuses on social activities emphasizes the interaction between science, technology, society, and the natural environment. Critical literacy is defined by Lewinson, Flint, and Van Sluys (2002) as deviating from the norm, questioning multiple perspectives, focusing and acting on sociopolitical issues, and promoting social justice. Due to these characteristics, critical literacy has become the paradigm of critical citizenship education today (Sjostrom & Eilks, 2018). It is well known that critical citizenship includes characteristics such as scientific literacy, exposure to societal situations, the defense of rights, and self-awareness. In light of these shifting paradigms, Sjostrom, Frerichs, Zuin, and Eilks (2017) dubbed this vital aspect of SL Vision III, which emphasizes the role of science and technology in social and economic development, the Science and Technology Dimension. The emphasis is on acquiring the individual's desired knowledge and cognitive skills; learning is unrestricted due to personal development (Sjostrom & Eilks, 2018). It implies

a focus on emancipation and social participation in science education. Figure 1 illustrates the dimensions of SL.

Wang et al. (2019) stated that, based on these visions, there are three approaches to SL: the knowledge-based approach, which emphasizes the significance of scientific knowledge; the contextual approach, which demonstrates the significance of science by considering science teaching and learning in context; and the critical approach, which emphasizes the importance of teaching and learning. Using SL skills can aid in the development of critical thinking and the application of classroom knowledge to real-world contexts (Meyer et al., 2018; Miller, 2010). There is a close relationship between SL and the economic well-being of countries (Demirel & Caymaz, 2015), which is the primary reason why students need support in this area (Khusniyawati & Suryanti, 2018). Literacy skills can be used as a foundation for understanding the environment and solving problems related to science in the future.

SL explains the accumulation of scientific knowledge. This approach is the foundation of SL, which includes comprehension of the concepts and processes involved in the production of scientific knowledge. In other words, it is necessary to understand not only the facts but also their significance and how scientists generate new knowledge. Due to the complexity of our world, it is difficult to determine which ideas are reasonable and which are uncertain (Keith & Beins, 2017). Thanks to SL, it is acknowledged that some adjustments are necessary when making the best decisions and when new information becomes available. The goals of SL include the application of acquired knowledge and skills at the appropriate time and place, problem analysis, producing arguments, drawing conclusions, and reasoning (Martín-Gámez & Erduran, 2018).

To improve the SL of primary school students, it is necessary to encourage students to engage in active communication, collaborate, and assist one another. By working collaboratively, students with SL skills will be able to exchange information and share their knowledge (Nisaâ, Rusilowati, & Wardani, 2019). One can say the following about the characteristics of a student with SL. Understanding and familiarity with scientific knowledge, terms, principles, and process skills. Understands the impact of science on daily life as well as the relationships between science, society, and the environment. Utilizes scientific knowledge to make important decisions and solve problems in daily life (Demirel & Caymaz, 2015). When primary school students acquire SL skills, it is expected that

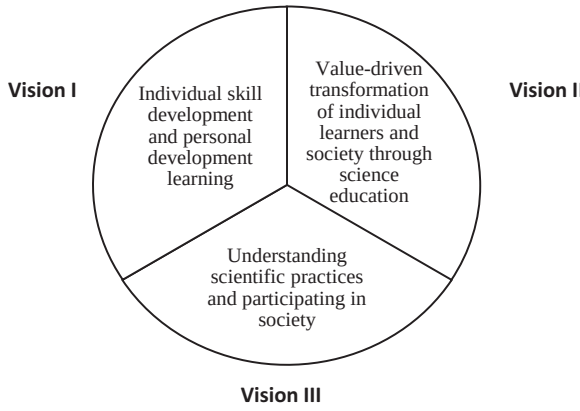

Fig. 1. Three visions of scientific literacy (Sjostrom et al., 2017)

they will attempt to deal with science and practice by doing. In the education programmes of many countries around the world, gaining scientific literacy in primary schools is shown as a target (Dragos & Mih, 2015; Udompong & Wongwanich, 2014). Scientists also emphasise that scientific literacy and scientific attitude should be acquired at an early age (Murcia, 2007; Smith et al., 2012). In this sense, it is important to lay the foundations of scientific literacy skills at an early age.

BIBLIOMETRIC ANALYSIS

It is becoming increasingly important to track newly published works, identify their distinguishing characteristics, analyze the citation relationship networks between publications based on a variety of criteria, comprehend the present, and draw conclusions about the past and future (Engels, Ossenblok, & Spruyt, 2012; Henriksen, 2016; Larivière, Archambault, Gingras, & Vignola-Gagné, 2006; Rowlinson, Harvey, Kelly, Morris, & Todeva, 2015). Access to information and document analysis based on a variety of criteria have become significantly more efficient in the follow-up of publications created by researchers and the analysis of citation or relationship networks between publications. The bibliometric analysis method, which was initially defined by Pritchard (1969), is one of the methods that can be used for this purpose. Bibliometric research reveals the current status, orientation, and growth of studies within a discipline's literature. Bibliographic research permits analysis by citation, subject, country, academic journals, and article distribution (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021). It also reveals the interest in science, the interaction of that science with other sciences, the level of internationalization in the relevant science, etc. Today, articles published in journals scanned in the citation indexes of the Web of Science WoS: Web of Science Core Collection by Clarivate Analytics database are widely accepted in the academic community; consequently, this database is frequently utilized in bibliometric analyses (Birkle, Pendlebury, Schnell, & Adams, 2020; Li, Rollins, & Yan, 2018; Pranckutė, 2021).

Literature analyses on SL have been conducted for a variety of purposes (Li & Guo, 2021). Laugksch (2000) has conducted a historical review of the SL literature. In the International Journal of Science, Yore, Bisanz, and Hand (2003) compiled a 25-year review of SL research in education. Miller (2004) conducted a review in order to acquire more extensive knowledge about SL. Roberts (2007) conducted a study comparing science and SL. Roberts and Bybee (2014) investigated the definition of SL in the context of the new curriculum. Using visual citation analysis, no research was found examining studies on SL. In this study, bibliometric analysis of SL will be used to map its historical development. Using data visualization, graphing, and citation analysis, it is also intended to evaluate the SL literature comprehensively and objectively. Using citation analysis to compare countries, journals, and authors regarding SL, a 21st-century skill that is emphasized by the OECD, the study examines current and future trends from a unique perspective by comparing countries, journals, and authors.

AIMS OF THE STUDY

Science education aims to develop students' scientific literacy skills. Students in primary school should be introduced to scientific literacy in an appropriate context for their cognitive development, such as in their immediate and personal environments (Suryanti & Lede, 2018).

Students in primary school are curious about their age. These students are not only educated formally in school, but they can also learn from their observations, hypotheses, and discoveries regarding the surrounding environment. For a society to have a high rate of SL, young children should develop an interest in science (Udompong & Wongwanich, 2014). Kaya et al. (2012) state that acquiring SL at a young age will allow students to develop a broader perspective in their future lives. Effective and correct instruction of SL skills to primary school students will not only contribute to their educational success, but also to the growth of society. Consequently, acquiring SL skills at a young age will pave the way for scientific advancements.

Continued efforts to improve the quality of human resources are required to compete in the global marketplace and keep up with scientific and technological advancements. There are many articles (Anderson, Justement, & Bruns, 2020; Fitzgerald, 2012; Garson, 2002; Harlen & Qualter, 2004; Jimenez & Menendez Alvarez-Hevia, 2021; Keith & Beins, 2017; Khusniyawati & Suryanti, 2018; Majetic & Pellegrino, 2014; Peacock, 2005; Smith et al., 2012; Suryanti & Lede, 2018) published in the WOS database in the field of SL in primary school. These studies must be analyzed based on particular criteria and presented to researchers. Due to the rapid increase in SL research, there is a need for new studies that evaluate the existing literature and reveal the newest tendencies. For this purpose, bibliometric analysis was conducted on studies about SL in primary schools that were analyzed and indexed in WOS.

This study aims to analyze and evaluate the studies published in this database on SL in primary school using bibliometrics and content analysis. The current study is limited to the studies published in the WOS database on the SL abilities of primary school students. In light of this study, the SL literature will be viewed through a wide lens and new insights will be gleaned from it. Since the study spans the years 1993–2021, the results can be used to compare SL over time. In this study, the following are the research questions (RQ) for SL studies in the Web of Science database.

RQ 1: What is the publication year distribution?

RQ 2: How are the top keywords, countries, and organizations distributed?

RQ 3: Who are the most-cited authors and journals?

RQ 4: How are the variables, method, data collection tool, distribution of populations in SL studies?

METHOD

Article selection process

Content and bibliometric analysis were used in this study. Under separate headings, the article selection process for both types of analysis is presented below.

Article selection process for bibliometric analysis. This study employs bibliometric analyses to put the studies on SL in primary school to the test using the Web of Science (WoS) database. Between 1993 and 2021, a total of 4,979 studies on education research related to the key concept of "scientific literacy" in the WoS were included. Using the advanced search function, the keywords entered in the topic section were "primary." For consistency, the

language was set to "English," and the document type was set to "articles." As a result, 145 articles were included in the study (December 13, 2021). Then, in tab-delimited (Win) file format, full records and cited references were downloaded. The file was loaded into the VOS Viewer program.

Article selection process for content analysis. The keywords used were "scientific literacy" in the topic section and a range of commonly used terms, listed as follows: "primary school" OR "primary education" OR "primary teachers" OR "primary students" OR "pre-service teachers". The language was selected as "English" and the document type was determined as "articles". Among the articles about SL in primary school accessed 60 articles between 2002 and 2021 were included in WOS (December 20, 2021).

Analyses of data

The VOS viewer program was used to generate bibliometric maps of the most cited words, authors, countries, and most used words in the abstract section for the 145 articles accessed. The Publication Classification Form was used to analyze the content of the articles. This form is divided into four sections: *(1) study title, author(s), journal title, (2) methodologies, (3) data collection tools, and (4) sample population.* Three researchers conducted the analyses, and the coding was reviewed by an expert. The data were analyzed using descriptive statistics.

RESULTS

Findings of bibliometric analysis

Publication year. Figure 2 illustrates the distribution of Web of Science articles based on the number of years of research. Consequently, while the study's first article was published in 1993, the majority of the articles were published in 2020 ($N = 25$).

The most cited keywords

In the articles analyzed for this study, the most prevalent keywords were identified. In the VOS viewer software, the minimum number of keyword occurrences is set to 2, and 154 keywords are selected. Figure 3 illustrates the map that was generated.

The thickness of the lines represents the potency of the utilized keywords, the size of the circle represents the large number of articles, and the colors represent the publication cluster. Accordingly, scientific literacy ($N = 22$), science education ($N = 7$), nature of science ($N = 4$), primary education ($N = 4$), disciplinary literacy ($N = 2$), science writing ($N = 2$), and picture book ($N = 2$) are the most used terms.

Figure 4 illustrates the distribution of the most cited keywords by years. "Competence-based education", "developmental research", "climate change", and "science curriculum" are popular topics in SL.

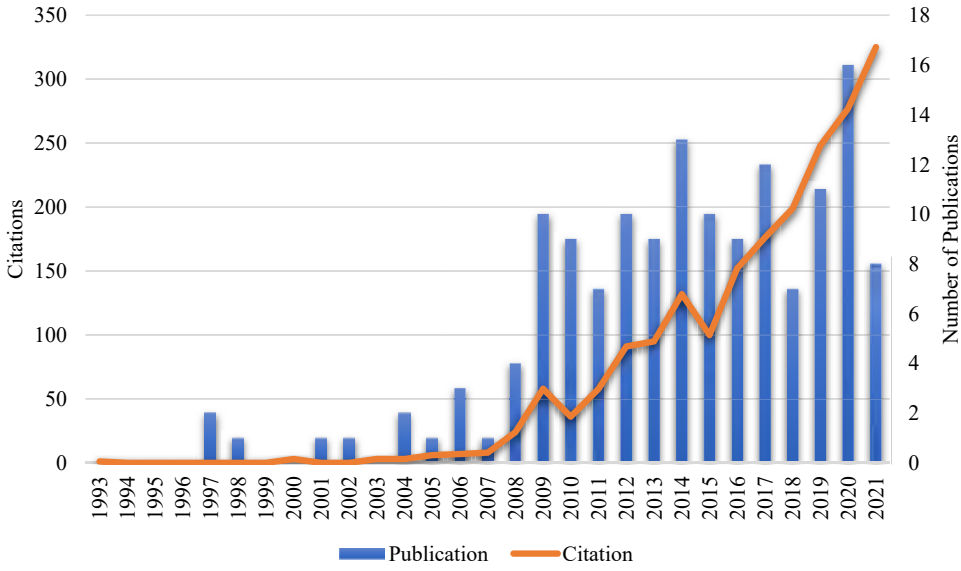

Fig. 2. Citations and publications throughout time

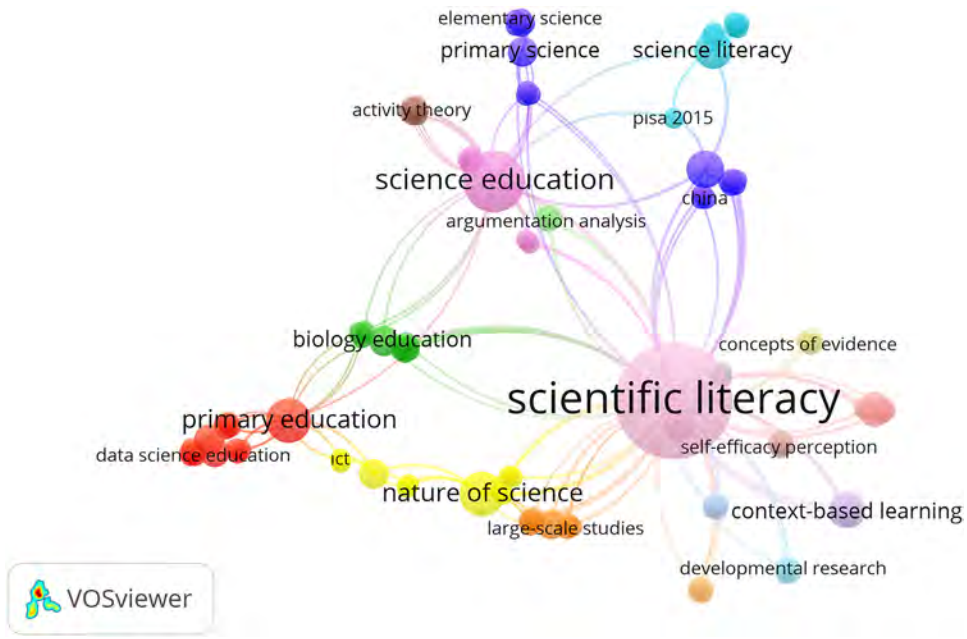

Fig.3. The most cited keywords about SL in primary

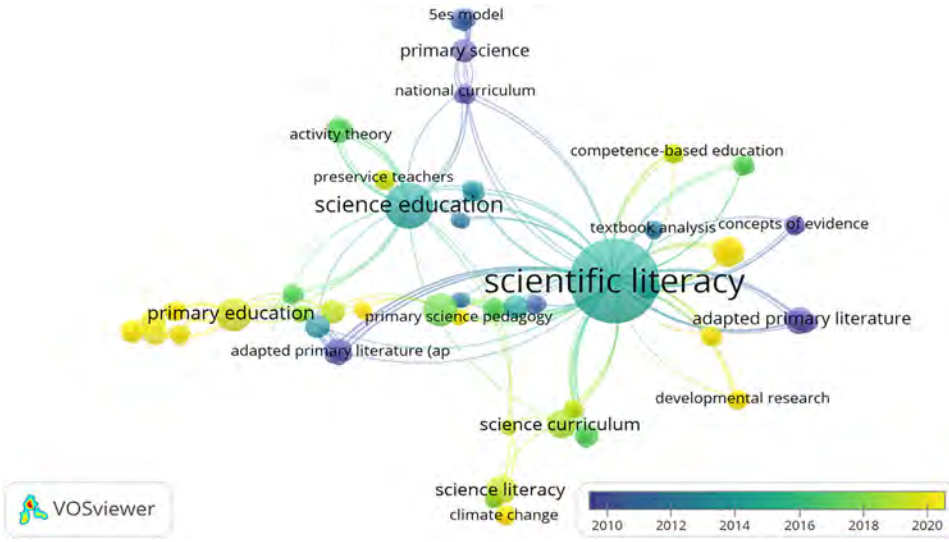

Fig. 4. The most cited keywords by years

The most-cited countries

The bibliometric networks of the publications included in the study were illustrated on a map to identify the countries with the most citations. In the VOS viewer software, the minimum number of source documents was changed to 1 and the minimum number of citations per country was set to 1. Figures 5 and 6 demonstrate the generated maps. Accordingly, Table 1 displays the nations with the highest number of citations in the study.

With four publications, the Australian Council for Educational Research (ACER) received the most citations. The following publications are listed: PISA 2015: Reporting Australia's Results (2017), PISA 2018: Reporting Australia's Results (2019), and A Teacher's Guide to PISA Scientific Literacy (2013).

The most-cited organizations

The minimum number of documents for an organization has been changed to 2 and the minimum number of citations for an organization has also been set to 2. Figure 7 displays the most-cited companies. Weizmann Institute (Citations = 65, Documents = 2), Australian Council Education Research (Citations = 100, Document = 1), University Alberta (Citations = 62, Document = 2), and University Minnesota (Citations = 32, Document = 2) are the most-cited institutions. Figure 8 illustrates the most frequently cited organizations by years.

The most-cited journals

The VOS viewer's co-citation minimum number of source citations is listed as 7 for the most cited journals; consequently, bibliometric mapping has been created for 27 journals. The

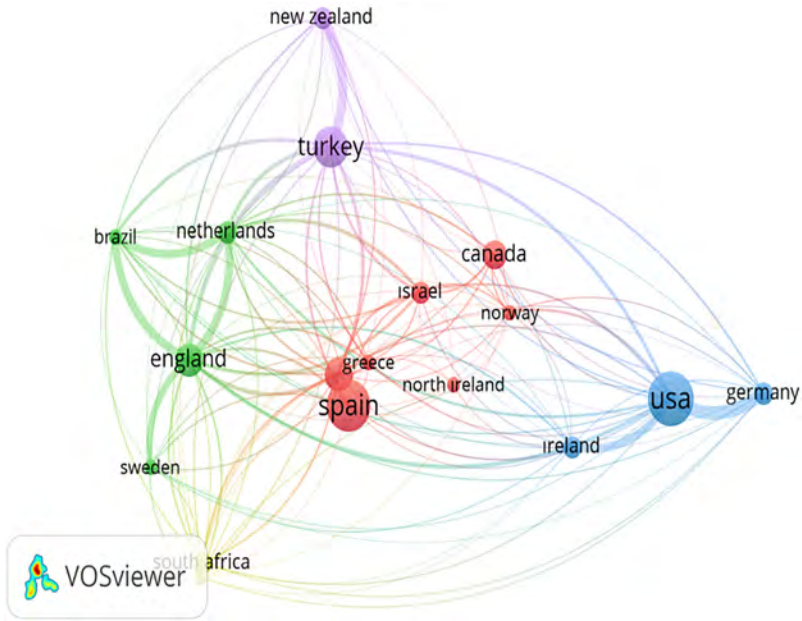

Fig. 5. The most-cited countries

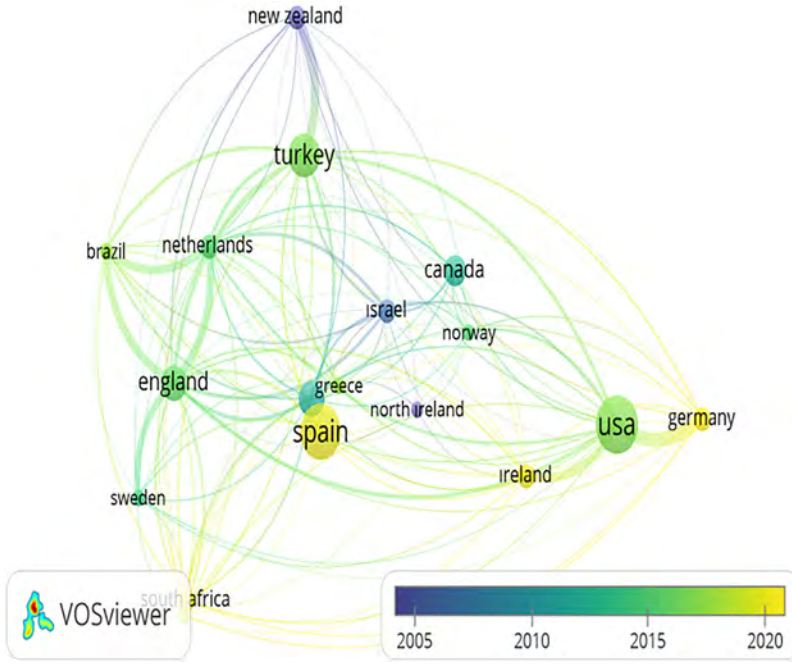

Fig. 6. Most cited countries by years

Table 1. Document and publication citation rankings for the top eight countries

Country	Documents	Citations	Country	Documents	Citations
Australia	4	123	Turkey	6	44
USA	10	73	New Zealand	2	38
Israel	2	65	England	4	26
Canada	3	63	Ispania	9	19

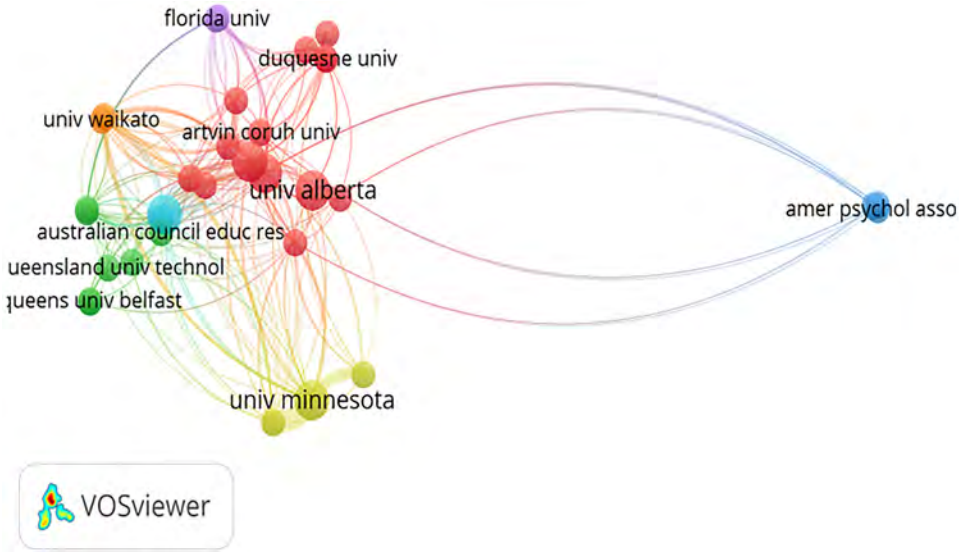

Fig. 7. The most-cited organizations

generated map is illustrated in Fig. 9. Consequently, Int Sci Educ (Citations = 155), Sci Educ (Citations = 137), J Res Sci Teach (Citations = 131), Res Sci Educ (Citations = 36), and JSci Teach (Citations = 22) are the most cited journals. Co-citation analysis and possible sources are highlighted.

The most-cited authors

For the most-cited authors, a citation analysis was conducted. Accordingly, the following are the most-cited authors: Bybee (1 Documents, 100 Citations), McCrae (1 Documents, 100 Citations), and Norris (1 Document, 62 Citations). The generated map is shown in Fig. 10. Table 2 provides information about the authors and citations.

Figure 10 illustrates the most frequently cited authors. For the most-cited authors, a co-citation analysis was conducted. OECD (2016; Citations = 23), Osborne (2003; Citations = 17), National Research Council (2012; Citations = 15), Norris (2003; Citations = 12), Laugksch

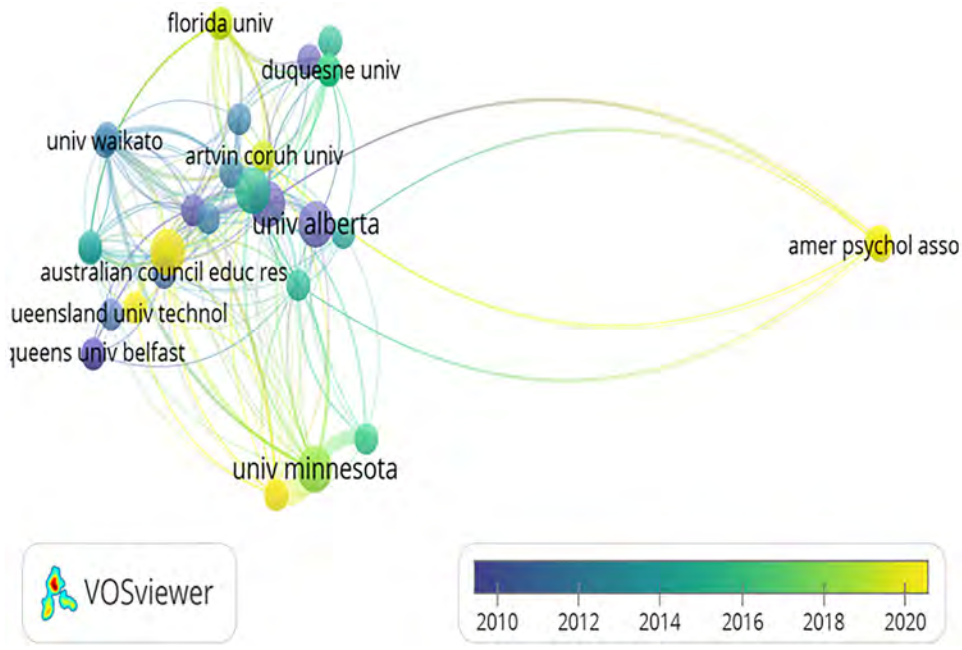

Fig. 8. The most-cited organizations by years

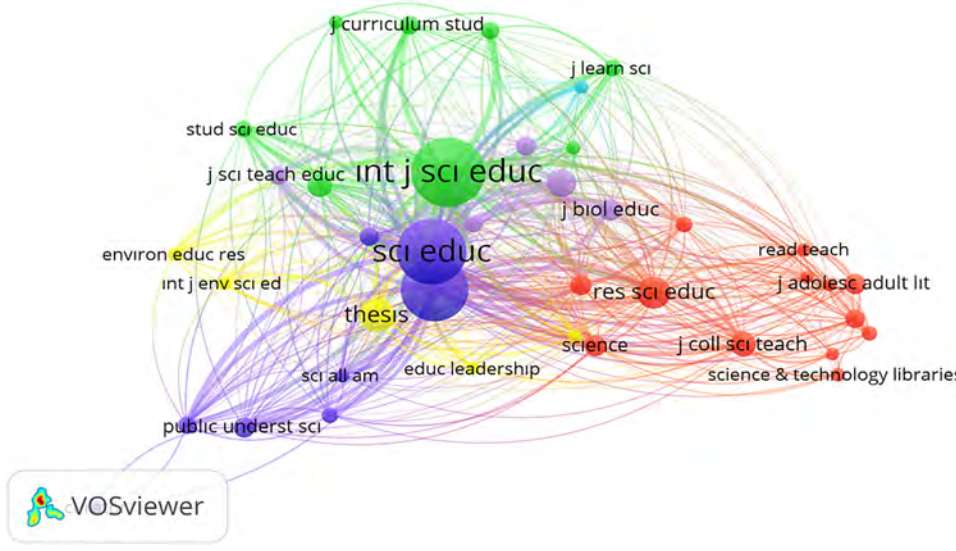

Fig. 9. Most cited journals (co-citation analysis)

Fig. 10. The most-cited authors (citation analysis)

Table 2. The data regarding authors and citations

R	Authors/Authors number	Title	C	ACY
1 and 2	Bybee, R. and McCrae, B. (2011)	Scientific literacy and student attitudes: perspectives from PISA 2006 science, *International Journal of Science Education*, 33(1), 7–26.	100	8.42
3 and 4	Norris, S. P. and Philips, L. M. (2003)	How literacy in its fundamental sense is central to scientific literacy. *Science Education*, 87(2), 224–240.	62	26.8
5 and 6	Baram-Tsabari, A. and Yarden, A. (2005)	Text genre as a factor in the formation of scientific literacy. *Journal of Research in Science Teaching*, 42(4), 403–428.	45	2.5
7 and 8	Calik, M. & Coll, R. K. (2012)	Investigating socio-scientific issues via scientific habits of mind: development and validation of the scientific habits of mind survey, *International Journal of Science Education*, 34:12, 1909–1930.	37	3.55
Other	54 authors		$3 \leq C <$ 21	—
	11 authors		2	—
	17 authors		1	—
	26 authors		0	—
	4 authors		0	—

R: Total number of authors, C: Citation, ACY: Average citation per year

(2000; Citations = 11), and Roberts (2007; Citations = 9) are the most-cited authors, according to the results of the analysis. The generated map is shown in Fig. 11.

Content analysis findings

Variables in primary articles on SL. Table 3 lists the variables examined in 60 studies conducted between 2002 and 2021. According to the results, the most frequently mentioned variables in the articles are "Argumentation" (N = 11), "Approaches" (N = 10), and "Evaluation with PISA and politics" (N = 8). In the reviewed articles, numerous other variables, including disciplinary literacy, environmental literacy, media literacy, scientific and mathematical literacy, data literacy, and early SL, were also examined.

Method trends. The analysis reveals that 28% of the articles are quantitative design, 33% are qualitative design, 18% are mixed design, and 20% are compilation work. The most popular quantitative research designs were quasi-experimental (10%) and descriptive (15%). Table 4 displays methodological trends.

Data collection tools. According to the findings of the research, questionnaires (37%, N = 22), interviews (25%, N = 15), and documents (15%, N = 9) are utilized frequently in articles. Figure 12 illustrates the frequency and distribution of data collection tools.

According to Fig. 12, questionnaires and interviews are used more than others in SL research. The use of academic tests and alternative assessment tools is 5%. Alternative assessment tools include some tools used in the learning process such as project-based assignments,

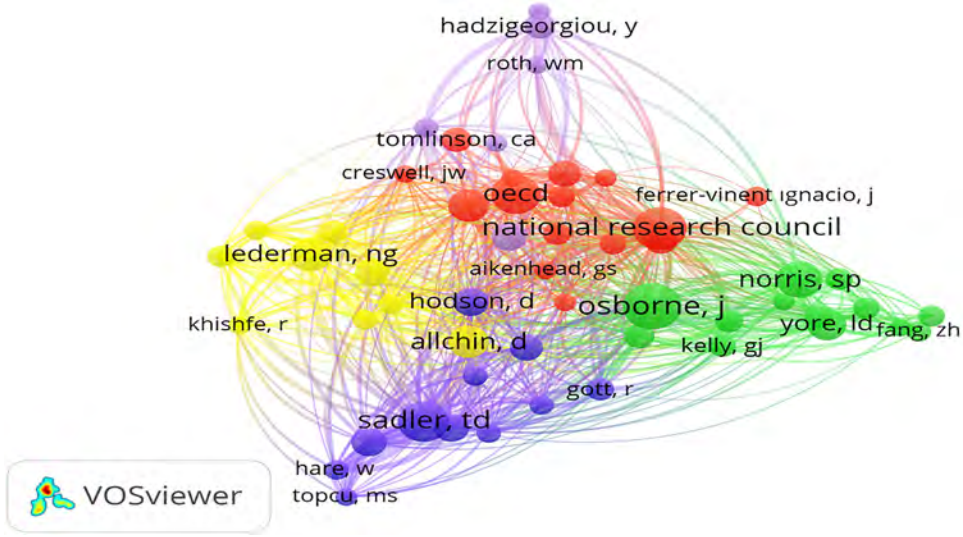

Fig. 11. The most-cited authors (co-citation analysis)

Table 3. The frequency of the examined variables in the articles

Variables			
Codes	Subcodes	TA*	%
Argumentation	- the argumentation and scientific literacy model - argumentation analysis - argumentation about socio-scientific issues - Toulmin argumentation - nature of science - scientific inquiry - language of school science	11	18
Approaches	- constructivist didactic proposal - design-based research - disciplinary approach - inquiry-based science - STEM curriculum - differentiated instruction - inquired-based integrated scientific literacy - constructivist approach - multilevel approach	10	17
Evaluation with PISA and politics	- USA, Turkey, New Zealand, China	8	13
Literacy variables	- disciplinary literacy - environmental literacy - media literacy - scientific and mathematical literacy - data literacy - early scientific literacy	7	12
Cognitive variables	cognitive abilities, cognitive perspectives, science knowledge, critical thinking	6	10
Technology	- scientific technological competence - digital and media skills, - The mobile Naturel Science Learning, - science technology and society	6	10
Teacher development	- scientific literacy instruction, - projects, - inclusive strategies - attitudes towards science education - discourse analysis	5	8
Materials/practices	- textbook activities - science fiction movie - drama activities	3	5
Outdoor education	- museums - outdoor and technology	2	3
Pedagogy	- Pedagogical content knowledge and epistemological profiles	2	3

*TA: Total number of articles

Table 4. The trend of Research Methodologies (RM) on SL in primary school by the year

RM	Research Designs		N	Years				% of RM
				2002–2012	2013–2015	2016–2018	2019–2021	
Quantitative	Non-experimental	Descriptive	9	—	2	4	3	15
		Cross-sectional	1	—	1	—	—	1.66
		Longitudinal	1	—	—	—	1	1.66
	Experimental	Quasi-experimental	6	1	2	2	1	10
	Total		**17**	1	5	6	5	**28.3**
Qualitative	Document analysis		12	1	3	2	6	20
	Case study		4	1	1	1	1	6.6
	Triangulation		4	3	—	—	1	6.6
	Total		**20**	5	4	3	8	**33.3**
Mixed	Triangulation		9	1	3	3	2	15
	Explanatory		2	—	1	1	—	3.2
	Total		**11**	—	3	4	2	**18.3**
Other	Review		**12**	2	2	5	3	**20**

RM: Research Methodologies, N: Number of Research

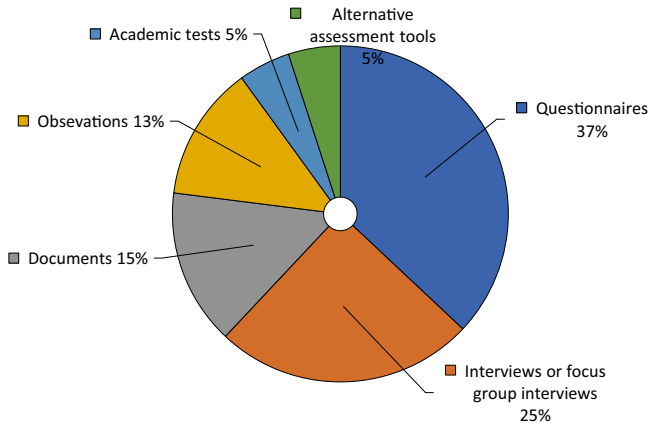

Fig. 12. Frequency of use of data collection tools

problem-based assignments, presentations, reports, reflective pieces. Figure 13 illustrates the frequencies of the data collection tools by years.

Examining the frequency of use of data collection tools over time reveals that questionnaires and interviews are prevalent in every era. Alternative assessment tools (2010–2012–2017, total $N = 3$) and academic tests (2010–2014–2015, total $N = 3$) are the least utilized over the three-year period 2010–2017.

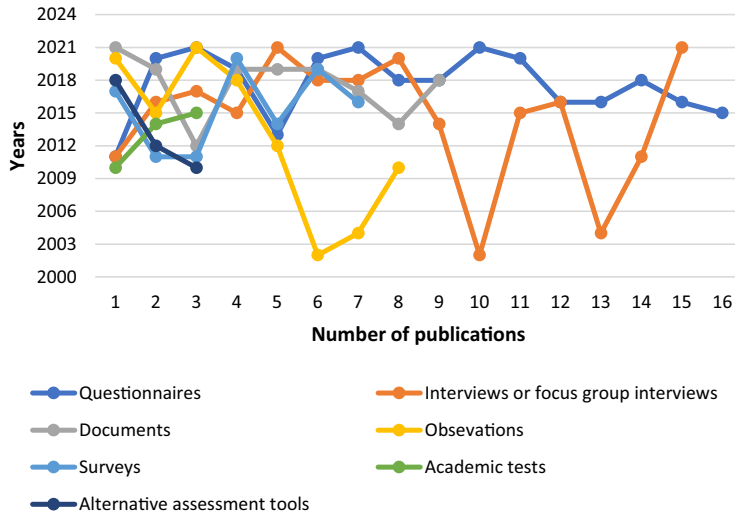

Fig. 13. Frequency of use of data collection tools by years

Sample populations. Figure 14 shows the number of studies on different sampling groups in the articles. Figure 14 illustrates that primary school students ($N = 21$), documents ($N = 15$), and graduate students ($N = 12$) were the most popular sample groups. At a minimum, kindergarteners ($N = 1$) and researchers ($N = 1$) were selected as sample groups.

Figure 15 shows the distribution of sample groups by years. According to these findings, primary school (K-1) student research will increase in the 2020s.

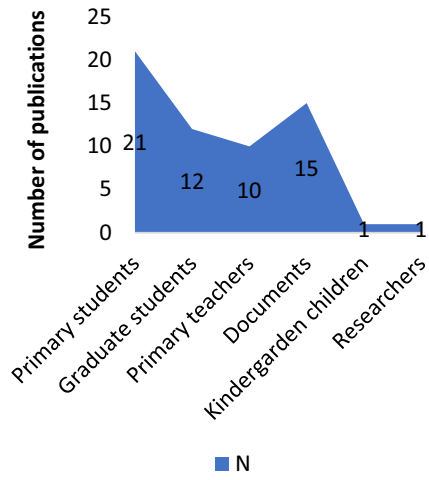

Fig. 14. Frequency of use of sampling groups in the article

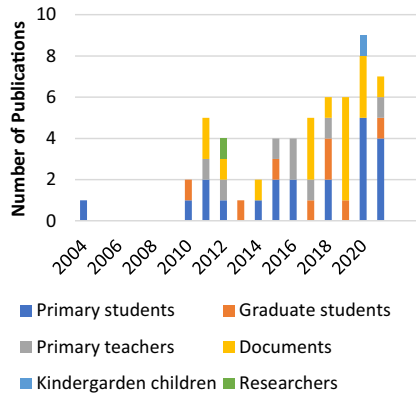

Fig. 15. Distribution of sampling groups by years

DISCUSSION

Important information is provided to researchers by a thorough examination of the literature in terms of its distribution and by keeping up with the changing trends in scientific studies. In contrast to content analysis and document analysis, bibliometric analysis considers changes in the literature, such as author, journal, number of citations, country, etc. By analyzing the data collected based on the collective bibliographic data produced by other scientists, bibliometric analysis can reveal objectives regarding the field's structure, social networks, and current research interests. In addition to descriptive statistics, "citing" and "co-citing" analyses are employed (Zupic & Čater, 2015). In this study, a bibliometric analysis and content analysis of SL in primary school articles published between 2002 and 2021 in the WoS database were conducted. Examining the findings revealed that the number of studies and citations increased exponentially over time. In 1993, there were two studies on SL; by 2020, there will be twenty-four. The emphasis on literacy and 21st-century skills in curricula around the globe may have led researchers to this topic. Bankson (2009), Hernández-Torrano and Ibrayeva (2020), and Julius et al. (2021) have reported that the increase in bibliometric research publications in various fields over the past decade is remarkable. In Jho's (2018) bibliometric analysis study, it was determined that the number of publications on the nature of science increased between 1965 and 2018, with a peak in 2014. Li and Guo (2021) also reported that SL bibliometric analysis research on socio-scientific issues increased between 2008 and 2019.

Science education, primary school, scientific literacy, and nature of science terms are the most frequently used keywords. While determining the general trends associated with SL between 2010 and 2014 was the objective, it can be said that specialized studies in various samples garnered attention in the years that followed. SL, science education, and information education were the most frequently used keywords in Effendi et al. (2021) bibliometric analysis of SL in education between 1984 and 2020, and the lack of studies in the field of SL. As one of the essential skills for preparing individuals for the future (OECD, 2014), it is a topic that requires greater emphasis.

The United States, Spain, and Turkey are the leading countries for SL study. However, based on the number of citations, which is generally accepted as a measure of the articles' widespread impact, it was determined that Australia had the most publications, followed by the United States, Israel, and Canada. The first study in a field is the one most frequently cited by subsequent researchers. Citations are an important indicator of a publication's impact value (Supriadi, Supriyadi, Abdussalam, & Rahman, 2022). The majority of publications addressed Israel and New Zealand prior to 2005, the United States, Turkey, and England between 2015 and 2020, and Spain, Germany, and Ireland after 2020. The United States is the source of numerous publications in the field of literacy; Yesiltas and Evci (2021) on computer literacy; Julius et al. (2021) on mathematics education research; Alagu and Thanasgudi, (2019) on literate research; and Effendi et al. (2021) on SL in science and physics education. Following the United States are Canada, Australia, and Turkey. Jho (2018) also reported the number of articles on the nature of science aimed at the United States and Turkey.

Australian Council of Education Research (ACER) received 100 citations for an article, making it the most cited organization. ACER 2011; 2013; 2017; 2019, an organization that conducts research on educational standards and other topics and publishes documents, is anticipated to receive a large number of citations. The Weizmann Institute and the University of Alberta follow with 65 and 62 citations to two publications, respectively. According to Li and Guo (2021), the National Science Education Standards is the most popular study published on SL by the National Research Council (1996). Universities are the most prolific publishers, according to numerous bibliometric analysis studies (Bozdogan, 2020; Hernández-Torrano & Ibrayeva, 2020; Yesiltas & Evci, 2021; Yesiltas & Seker, 2021). According to Kolle (2017), The University of Granada in Spain and Charles Sturt University in Australia have contributed more publications to the field of information literacy than universities in the United States. As educational and scientific institutions, universities have a substantial impact on the number of publications produced in a country, despite minor subject-specific variations.

Figure 7 indicates that Science Education, International Science Education, and Journal of Research in Science Teaching have the largest areas among the journals with the most publications. Similar findings were found in the study conducted by Yao and Guo (2018); these journals have published approximately 70 percent of research involving science teachers. In the field of science education, it can be deduced that the aforementioned journals are highly effective and important. Price's law is expressed in librarianship and information science as "the square root of the total number of journals containing half of the total number of articles" (Egghe & Rousseau, 1990, p. 362). According to this study, 145 articles were collected from 27 journals, and six of these journals were heavily cited, in accordance with Price's law.

Bybee & McCrae (2011), Philip and Norris (2009), and Calik and Coll (2012) are the most cited works. Leading trends in citing a particular article indicate the article's significance in the literature. The number of citations for publications with multiple authors is increasing. The Pareto Law, also known as the 80/20 rule, is based on the principle that 80% of products can be produced with 20% of resources (Egghe, 1986, p. 55). In the present study, it was determined that 120 different authors produced a total of 145 publications. 8 authors produced 9 studies with over 22 citations each. The given numbers do not comply with the Pareto principle. 60% of authors in a field contribute with one article, 15% with two articles, and 7% with three articles, according to Lotka's law (Rowlands, 2005, p.7). The greatest number of authors in this study contributed to the field with an article. The research results demonstrate Lotka's law.

The authors with the highest co-citation frequencies are OECD (2016), Osborne (2003), NRC (2012), Norris (2003), and Laugksch (2000). The OECD and NRC are the primary sources cited in the published reports on education, training, and SL. Co-citation is the occurrence of two items being referenced simultaneously, whereas bibliographic coupling exists in other articles (Cunill, Salvá, Gonzalez, & MuletForteza, 2019). The closer two authors are geographically, the closer they are related. Articles by Osborne and Norris are the most important literary references in the field of SL. As shown in Fig. 9, Osborne, Aikenhad, Lederman, Ksihefe, and Sadler make references to one another as researchers working on inquiry, the nature of science, and SL. This indicates that the authors collaborated on this work. In accordance with the previous co-citation finding, Table 3's content analysis of 60 articles reveals that argumentation, teaching approaches, PISA assessment, and literacy are the most researched variables.

In the methods of research in the field of SL between 2002 and 2021, qualitative studies were prevalent and qualitative research was the trend over time. According to Arduc and Kahraman (2021), the quantitative method is preferred for the content analysis of Turkish SL studies (62 theses and 28 articles). The increase in qualitative studies in the distribution of publications by years between 2019 and 2021 and the increase in other methods after 2016 demonstrates the significance of the concept of SL and the subject's appeal. It is possible to interpret the rise in document analysis studies as a result of the difficulties researchers encountered at the time of data collection during the COVID-19 pandemic. It is possible to believe that longitudinal and cross-sectional studies are not preferred due to sample loss and time constraints. The necessity for the researcher to have both qualitative and quantitative approaches, as well as the complexity of the data collection and analysis process, may explain the low rate of the mixed approach over the years. Creswell (2009) cited as limitations of the mixed approach the need for different resources for researcher skills, time, data collection, and analysis. The distribution of data collection tools validates the findings of the method. The use of questionnaires, interviews, and scales is prevalent in SL studies, and the use of scales in the distribution by years has increased between 2002 and 2010 and since 2010. Observational data were collected in two studies in 2020 and 2021. The use of alternative assessment tools and achievement tests is minimal. Preparing for an achievement examination is a lengthy and laborious process. It is not surprising that the majority of researchers prefer measurement instruments (scales) whose validity and reliability have been previously investigated. In the majority of studies, observation and document analysis are used to control the data collected for triangulation purposes. In their content analysis, Arduc and Kahraman (2021) reported that scales and questionnaires were utilized more frequently to determine SL. When the research was analyzed based on the distribution of the sample, it was discovered that primary students studied more in 2020–2021. In contrast, documents concentrate on 2019. Studies conducted with prospective teachers vary by years. By demonstrating the significance of SL, various sample groups of researchers have garnered the attention of SL.

CONCLUSION

"Scientific literacy" is an essential term for the realization of educational visions and the competent upbringing of future generations. It is crucial for students to acquire SL at a young age in order to acquire 21st-century skills. This study aims to examine the research trends and general

framework on SL in primary schools using WoS data, an important database. 145 studies conducted between 1990 and 2021 and 60 studies conducted between 2002 and 2021 were analyzed bibliometrically and content-wise, respectively. According to the research, the number of studies on SL's primary has increased from the past to the present, with the majority of studies conducted in 2020. Between 2010 and 2014, the frequency of specialized keywords related to the topic was determined to be low, while the frequency of general words (such as SL, science education, and primary school) was high. While general trends were determined in the first few years, subsequent years were devoted to studies on various samples. This demonstrates that interest in the subject of SL persists in various primary school samples. Bybee and McCrae (2011) were the most frequently cited authors on SL in primary sources. The most cited countries on SL are the United States, Spain, and Turkey, and the most cited organization is ACER. The most frequently cited journals on SL (International Science Education, Science Education, Journal of Research, and Science Teaching) are significant, highly effective publications in the field of science education. There has been an increase in the number of document analysis studies, while the number of mixed studies has decreased. Alternative assessment and achievement tests are the least frequently used data collection instruments. On the basis of these findings, it is possible to recommend increasing the number of mixed studies and developing achievement tests using alternative assessment techniques for SL in primary schools.

The study concluded that scientific literacy in primary school is mostly promoted by organizations, journals or authors in developed countries. Developed countries are seen to encourage individuals to engage critically with science-related issues and to support their ability to make informed decisions about them. This broad approach to scientific literacy is consistently integrated across the curriculum. Critical thinking and active engagement are emphasized as important learning outcomes, along with basic literacy, scientific knowledge and competences and a contextualized understanding of science. Also noteworthy are the practices of integrating the various elements of scientific literacy across educational levels and disciplines such as science, history, geography, citizenship, health and media education.

LIMITATIONS

This study has some limitations. First, some significant studies may have been overlooked in the WoS database's data. Second, only English-language studies were included in the analysis; significant studies published in other languages, such as German and French, were omitted. The content analyses were conducted between 2002 and 2021, as a third point. On the basis of the aforementioned limitations, future research could expand the scope of the study by incorporating multilingual databases like Scopus and Eric's studies.

Ethical permission: Ethical permission was not required as only Web of Science data from the internet was used in the study.

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