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Analysis of Articles on the Nature of Science between 2015 and 2022

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It is evident that knowing the nature of science is a requirement for "science education", which serves as the basis of conscious citizenship. For this reason, articles concerning the nature of science that were published in the Web of Science and EBSCOhost database between 2015 and 2022 were examined in this study in order to establish a broad framework and develop a research road map. A qualitative design approach and a descriptive review method were used. The keywords "Nature of Science (NoS) and Science Education" and "Teaching of Nature of Science (NoS) and Science Education" were used. The majority of the 107 articles on the nature of science that have been examined preferred qualitative research designs, and "Science & Education" is the publication that has published the most articles on the subject in 2017-2018-2020, pre-service teachers were mostly preferred as the sample group, it was applied to groups of "21-50" people as the sample group, open reflective approach was preferred as the teaching approach, the most commonly used method-technique was "discussion", the activities used in the articles were generally standard, semi-structured interview form was preferred as the evaluation tool and "VNOS-C" was deployed as the questionnaire. Studies may be conducted within the boundaries of further lectures on the topic and internationally published theses.

Introduction

The world and politics will acknowledge that the 2030 agenda is a global strategic plan to overcome the current threats to people, the planet, and prosperity, and that "science" is the most potent tool (United Nations, 2015). Science is one of the 17 objectives of the 2030

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Agenda (United Nations, 2015). Science education should emphasize the nature of science, as per the 2030 Agenda, as this is recognized as a key component of global sustainability (UNESCO, 2016). In recent years, numerous worldwide appeals for improving student scientific literacy for informed citizenship have been made (NGSS Lead States, 2013; OECD, 2019). Two of the three competencies of scientific literacy in the US have been defined by the National Research Council (NRC) (Lead States, 2013) and the 2018 PISA framework (OECD, 2019) as procedural and epistemic knowledge. According to the general scientific norms, future humans should be scientifically informed, meaning they should possess the skills necessary to learn nature of science (NoS) and comprehend how science interacts with society. The integration of explicit, reflective teaching of NoS and scientific inquiry (SI) into conventional scientific content is considered a means of promoting the development of scientific literacy (Lederman & Lederman, 2014). One of the key elements of scientific literacy does understand NoS (Driver et al., 1996; Laugksch, 2000). Scientific literacy includes having the knowledge of NoS, and as such, NoS is seen as being essential to science education (Holbrook & Rannikmae, 2007; Laugksch, 2000). Learning about NOS helps students understand scientific practices and make educated judgments regarding socio-scientific issues (SSI) that affect their daily lives. In addition, learners could learn to accept science as a significant characteristic of contemporary culture, understand the variety of scientific methods that scientists followed in their investigations of scientific phenomena (Driver et al., 1996; Leach et al., 1997).

The objective of science education is to enhance students' comprehension of scientific concerns and enable those making educated selections about scientific issues. For scientific education, one of the commonly discussed subjects in scientific education research is the nature of science (Lederman, 2013). Integration of NoS into teaching is intended to help teachers learn science concepts, develop an understanding of science, enhancing interest in science, and provide effective teaching of science content for teachers, (McComas, 2020).

NoS covers subjects include presenting the ontological and epistemological foundations of science, outlining what science is, how scientists operate, and the theoretical underpinnings of the link between science and society (Clough, 2018). NoS has been defined by researchers in different ways (Allchin, 2014; Lederman et al., 2013; Matthews, 2012). Clough (2018) defined NoS as the epistemological, ontological, and social facets of science. Allchin (2014) used terms as such as “the practices of science," "science as a way of knowing," "ideas about science," "how science works," and "the identity and methods of a discipline" are used to describe NoS. Lederman (1992) indicates to nature of science as the "rules of the game" that lead to the evaluation of values and truth statements that are crucial to science and its knowledge growth, including the cultural and social embeddedness of science as well as the uncertainty of scientific knowledge. Similarly, McComas (2020) developed lists of principles that try to condense well-known and much more in-depth understandings of NoS in scientific education. According to Lederman et al. (2013) and McComas (2020), there is no single scientific procedure that consists of hierarchical steps, and scientific knowledge is experimental, inferential, and provisional, requires creativity, and is entwined with the culture. Additionally, hypotheses, laws, and theories are varied sorts of knowledge.

In the literature, there are studies on improving teachers' and students' understanding of NoS (Halai & McNicholl, 2004; Sormunen & Köksal, 2014; Torres et al., 2015), professional development studies on NOS for teachers (Golabek & Amrene-Cooper, 2011; Paraskevopoulou & Koliopoulous, 2011), and improving teaching sources with NoS (Ferreira & Morais, 2013; Taber, 2008).Both national and international studies tend to take NoS into

consideration.

It is seen that teachers' views on aspects of NoS are generally inadequate, mixed, diverse, too simple, and inconsistent, and that teachers cannot fully match their views on NoS with their view of the existing knowledge of science (Adedoyin & Bello, 2017; Garcia-Carmona et al., 2011; Golabek & Amrane Cooper, 2011; Hanson, 2015; Kite et al., 2020; Liang et al., 2009; Ma, 2009; Mulvey & Bell, 2017; Onijamowo, 2010; Vazques-Alonso et al., 2013).It has been noted that many students at all levels of education hold fixed and differing views about NoS and adhere to an unpredictable and unstable understanding of it (Sormunen & Köksal, 2014; Dorji et al., 2022).

According to McComas and Clough (2020), there are generally three ways to teach NoS in scientific classes: indirect approach, the historical approach, and the open-reflective approach. Many studies have shown that using an open-reflective approach has a positive effect and change in understanding the NoS (Abd-El-Khalick, 2013; Adibelli-Şahin & Deniz, 2017; Ağlarcı et al., 2016; Çelik & Bayrakceken, 2012; Pliouras et al., 2017; Rudge & Howe, 2009; Smith & Scharmann, 2008). According to a few studies, the historical approach is a successful teaching strategy (Allchin, 2014; Chen, 2011; Nur & Fitnat, 2015). Other studies have argued that it is not an effective method (Abd-El-Khalick & Lederman, 2000; Paraskevopoulou & Koliopoulos, 2011; Mudavanhu & Zezerwa, 2017). A good deal of research has indicated that the indirect approach to teaching NOS is ineffective (Bell et al., 2011; Kim & Irving, 2010; Moss et al., 2001).

In the national literature review, there were review studies on NoS in science education (Caymaz, 2022; Ince & Sözgelen, 2015; Ocak & Yeter, 2018; Uçer-Erdemir & Dinçol-, Ozgür, 2023). Ince and Sözgelen (2015) reviewed NoS-related studies published in SSCI/SCI journals throughout the previous decade. Ocak and Yeter (2018) studied theses and publications from 2006 to 2016 using the National Thesis Center and ULAKBIM databases to assess NoS trends. Caymaz (2022) examined NoS teaching theses published in Turkey between 2005 and 2020. Uçer-Erdemir and Dinçol-Ozgür (2023) determined the trend by conducting a content analysis of graduate theses on NoS in Turkey. Until 2015, these studies examined the distribution according to research design, year, journal, sample group and size, and evaluation tools, but no study was found to reveal the trend between 2015 and 2022. In addition, there were no studies examining the approaches, methods, and techniques used in NoS teaching and the tendency regarding the distribution of activities. The current study is thought to be useful for researchers in terms of identifying gaps in the literature by examining the trends of articles published in the field of NoS between 2015 and 2022. The study is also expected to contribute to the field by examining the approaches, methods and techniques used in teaching NoS and the distribution of activities. In this framework, the aim of the research is to uncloak the trend in NoS articles between 2015-2022, to determine the blanks in the literature and to contribute to researchers for future studies. Since it was not possible to examine various scientific publications, the research was limited to the last seven years and two internationally recognized databases with the highest number of articles. In this context, the articles in the Web of Science and EBSCOhost databases between 2015 and 2022 related to the nature of science (NoS) were analyzed and answers to the following research questions were sought:

(1) How are the articles distributed on NoS based on research designs?
(2) How are the articles distributed on NoS according to years?

(3) How are the articles distributed on NoS based on the journals in which they are published?
(4) How are the articles distributed on NoS based on sample/study group?
(5) What is the distribution of the sample sizes of the articles on NoS?
(6) How is the distribution of NoS related articles based on teaching approach?
(7) What is the distribution of teaching methods and techniques in the articles on NoS?
(8) What is the distribution of assessment tools in the articles on NoS?

Method

Research Design

The study was conducted with the descriptive review method, which is one of the qualitative research designs. The descriptive review method is research aimed at determining general trends in the field by examining independent qualitative and quantitative studies together (Çalık, 2019). In this type of research, a systematic process is followed, as many studies as possible are accessed and filtering and classification processes are carried out so that trends and patterns are identified in the studies (Yang & Tate, 2012). It is carried out by studying and thoroughly examining the research investigations in the form of themes or templates.

Collection of Data and Inclusion Criteria

The gathering of study data began on March 1, 2023, and continued until the data collection procedure was completed (April 3, 2023). During this time, special efforts were made to incorporate recently published research into the study. For the literature review, the keywords "Nature of Science (NoS) and Science Education" and "Teaching of Nature of Science (NoS) and Science Education" were used. The articles to be included in the research were selected from the Web of Science (WoS) and EBSCOhost databases. It was emphasized that the sources included in the scope of the research should be publications published between 2015 and 2022 within the specified topic title. When the national literature is reviewed, there are various studies examining NOS studies between 1985 and 2014 (İnce & Sözgelen, 2015), 2006-2016 (Ocak & Yeter, 2018), 2005-2020 (Caymaz, 2022), 2015-2021 (Uçer-Erdemir & Dinçok-Özgür, 2023). No study examining articles on a large scale in the WoS and EBSCOhost databases between 2015 and 2022 could be found. In order to complete this deficiency and to determine current trends, studies conducted between 2015 and 2022 were analyzed. According to the search criteria, the time period (2015-2022), keywords (“nature of science and science education” and “teaching of nature of science (NoS) and science education”), language of publication (Turkish and English) and full-text accessible studies were included in the review. The researchers accessed 107 papers using these criteria.

Data Analysis Process

Inductive content analysis was preferred in data analysis. In this context, a table has been prepared to present the articles included in the research criteria in a collective summary. Tables only display frequencies. Each table and graph also includes a general explanation. The studies retrieved from the databases were reviewed and analyzed one by one. And the data was independently recorded in these tables by each researcher. The table consists of the following headings: publication code (CP), year of publication (YY), journal name (JN), research method (RM), sample group (SG), sample size (SS), instructional approach (IA),

instructional method and technique (IM), standard/developed (ESG) if there is an activity and assessment tool (AT).

The data were re-analyzed and controlled by researchers at different time periods in order to prevent data loss. A code was determined for each data. In the research, the initial letter "S" of the word "study" was taken and coded as S1, S2, ..., S107, and these codes were used when presenting the findings. A reliability analysis was carried out with the cross-checks of the researchers in the creation of codes and themes related to the studies. Using the formula suggested by Miles and Huberman (1994), "Agreement / (Agreement + Disagreement) x 100", the consensus among the evaluators was calculated as 91%. High coder reliability improves data analysis reliability (Miles & Huberman, 1994). In this context, an expert feedback on the codes and themes were submitted, and modifications and deletions were done to obtain an agreement before revealing the final version of the coding and summary list.

Findings

The findings related to the sub-problem of the study “How are the articles distributed on NoS based on research designs?” are presented in Table 1.

Table 1. Distribution of NoS articles according to research designs

Research Design	Frequency (f)	Code
Qualitative	65	“S1, S3, S4, S5, S6, S7, S9, S11, S12, S13, S15, S16, S17, S18, S19, S22, S23, S24, S27, S28, S29, S32, S33, S34, S36, S37, S39, S40, S41, S43, S44, S46, S48, S49, S50, S51, S54, S55, S57, S59, S60, S62, S63, S64, S65, S66, S68, S72, S75, S77, S78, S79, S80, S81, S91, S92, S93, S94, S96, S97, S98, S99, S100, S101, S103, S105 ”
Quantitative	21	“S2, S8, S21, S26, S35, S42, S52, S53, S69, S70, S71, S73, S74, S76, S82, S83, S84, S87, S88, S102, S107”
Mixed	21	“S10, S14, S20, S25, S30, S31, S38, S45, S47, S56, S58, S61, S67, S85, S86, S89, S90, S92 S95, S104, S106”

According to the Table 1, 65 of the 107 NoS teaching articles analyzed employed “qualitative research design", 21 were "quantitative research design" and 21 were "mixed research design".

The findings related to the sub-problem of the research “How are the articles distributed on NoS according to years?” are presented in Table 2.

Table 2. Distribution of NoS articles by years

Years	f	Codes
2015	14	“S2, S17, S21, S24, S26, S27, S37, S59, S60, S61, S62, S63, S97, S98”
2016	12	“S3, S4, S16, S32, S35, S40, S42, S56, S64, S65, S66, S99”
2017	15	“S12, S14, S15, S22, S28, S34, S38, S46, S52, S54, S58, S67, S68, S106, S101”
2018	15	“S1, S11, S29, S30, S41, S55, S69, S70, S71, S72, S73, S74, S75, S100, S102”
2019	12	“S5, S25, S44, S45, S50, S76, S77, S78, S79, S80, S81, S103”
2020	15	“S13, S19, S23, S31, S48, S49, S51, S82, S83, S84, S85, S86, S104, S106, S107”
2021	13	“S6, S7, S18, S33, S36, S39, S47, S87, S88, S89, S90, S91, S105”
2022	11	“S8, S9, S10, S20, S43, S53, S57, S92, S93, S95, S96”

In Table 2, it is seen that 15 studies were published in "2017, 2018 and 2020", 14 studies in

2015 and 13 studies in 2021.

The findings related to the sub-problem of the research "How are the articles distributed on NOS based on the journals in which they are published?" are presented in Figure 1.

Figure 1. Distribution of NoS articles according to the published journals

According to the Figure 1, the number of journals in which NoS articles are published is high. "Science & Education", "International Journal of Science Education", "Research in Science Education" and " International Journal of Science and Mathematics Education " journals have the highest number of NoS studies with 24, 15, 9 and 5 articles, respectively. In the specified date range, there are 2 journals publishing four studies on NoS, 3 journals publishing three studies, 6 journals publishing two studies and 26 journals publishing one study.

The findings related to the sub-problem "How are the articles distributed on NoS based on sample/study group?" are presented in Table 3.

Table 3. Sample/study group distribution of NoS articles

Sample Group	**Frequencies(f)**	**Code**
Pre-service teacher	51	"S1, S2, S3, S4, S7, S9, S10, S11, S12, S13, S14, S15, S16, S18, S19, S20, S23, S25, S26, S27, S28, S30, S31, S32, S36, S38, S39, S40, S41, S42, S43, Ç44, S45, S46, S47, S51, S53, S54, S55, S58, S59, S61, S66, S73, S74, S78, S85, S89, S93, S96, S100"
Teacher	19	"S6, S8, S12, S22, S24, S29, S34, S35, S37, S48, S49, S50, S52, S56, S57, S69, S92, S94, S105"

Student (44)	Kindergarten (1)	"S72"
	Elementary School (4)	"S60, S80, S91, S103"
	Secondary School (20)	"S21, S57, S63, S64, S67, ,S68, ,S76, S77, S79, ,S82, S84, S87, S88, S90, S94, S95, S97, S99, S101, S107"
	High School (12)	"S62, S65, S70, ,S71, S75, S81, S83, S86, S98, ,S102, S104, S106"
	University (9)	"S59, S61, S66, S73, S74, S78, S89, S93, S96"
	Postgraduate (5)	"S5, S25, S33, S85, S100"
Unspecified	3	"S69, S92, S105"

As can be seen in Table 3 is analyzed, 51 studies were conducted with "pre-service teachers," 44 studies with "students," and 19 studies with "teachers" in the sample/study group distributions of NoS teaching articles.

The findings related to the sub-problem "What is the distribution of the sample sizes of the articles on NoS?" are presented in Table 4.

Table 4. Distribution of NoS articles according to sample sizes

Sample Size	**f**	**Code**
1-10	16	"S6, S11, S22, S23, S24, S27, S33, S36, S39, S47, S55, S56, S72, S86, S99, S105"
11-20	22	"S2, S5, S7, S12, S13, S15, S19, S28, S29, S37, S38, S44, S45, S48, S52, S54, S60, S66, S75, S77, S78, S100"
21-50	32	"S1, S3, S10, S16, S25, S30, S34, S35, S42, S43, S50, S51, S53, S58, S61, S63, S64, S65, S68, S76, S79, S81, S84, S88, S91, S92, S96, S97, S103, S104, S106, S107"
51-100	23	"S4, S8, S9, S14, S17, S20, S31, S32, S40, S41, S46, S49, S57, S59, S62, S67, S69, S73, S83, S89, S94, S95, S101"
101-200	5	"S82, S85, S87, S90, S93"
201-500	4	"S18, S21, S71, S74"
501-…	2	"S26, S102"
Unspecified	3	"S98, S80, S70"

According to Table 4, it is seen that the sample distribution is "21-50 people" in 32 studies, "51-100 people" in 23 studies, "11-20 people" in 22 studies, "1-10 people" in 16 studies, "over 100 people" in 11 studies, and information on sample size is not provided in 3 studies.

The findings related to the sub-problem "How is the distribution of the articles about NoS according to NoS teaching approach?" are presented in Table 5.

Table 5. Distribution of articles according to the approach to teaching the NoS

Approach of Teaching NoS	**f**	**Code**
Open Reflective Approach	90	"S2, S3, S4, S5, S6, S8, S9, S11, S12, S13, S14, S15, S16, S17, S18, S19, S21, S22, S23, S24, S25, S26, S27, S28, S29, S30, Ç32, S33, S34, S35, S36, S37, S39, S40, S41, S42, S43, S44, S46, S47, S48, S49, S51, S52, S53, S54, S55, S56, S57, S58, S63, S64, Ç65, S66, S67, S68, S69, S70, S72, S73, S74, S75, S76, S77, S78, S79, S80, S81, S82, S83, S85, S86, S87, S88, S89, S90, S91, S94, Ç96, S97, S98, S99, S100, S101, S102, S103, S104, S105, S106, S107"
Historical Approach	9	"S1, S20, S30, S31, S50, S59, S60, S62, S71"
Indirect Approach	5	"S42, S61, S81, S92, S93"
The Family Resemblance Approach	6	"S7, S10, S38, S45, S84, S95"

According to Table 5, it is seen that "open reflective approach" is preferred in 90 studies; "historical approach" in 9 studies, "family resemblance approach (FRA)" in 6 studies, and "indirect approach" in 5 studies in the distribution according to the NOS teaching approach used in NOS articles.

The findings related to the sub-problem "How is the distribution of teaching methods and techniques in the articles on the NoS?" are presented in Table 6.

Table 6. Distribution of articles according to methods and techniques

Methods-Techniques	**f**	**Code of Study**
Discussion (Group, class)	48	"S1, S2, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S17, S19, S20, S22, S23, S24, S26, S27, S28, S30, S33, S34, S35, S36, S37, S38, S39, S40, S42, Ç44, S45, S46, S47, S49, S51, S52, S54, S55, S56, S57, S58, S60, S62, S105"
Reading	27	"S8, S11, S13, S15, S17, S19, S20, S22, S24, S25, S27, S28, S33, S35, S36, S39, S40, S45, S47, S49, S51, S52, S53, S55, S56, S57, S74"
Nature of science activities	29	"S3, S5, S9, S11, S15, S16, S19, S22, S23, S24, S27, S28, S29, S33, S34, S37, S40, S41, S42, S46, S48, S51, S52, S53, S56, S57, S63, S72, S102"
Inquiry	19	"S5, S8, S9, S18, S20, S23, S28, S34, S35, S36, S41, S43, S48, S49, S50, S52, S68, S71, S77"
Argumentation	10	"S1, S14, S38, S46, S53, S56, S81, S86, S96, S106"
History of science, historical narrative, history	30	"S1, S3, S5, S9, S17, S19, S20, S26, S27, S28, S30, S33, S37, S40, S42, S44, S46, S50, S52, S53, S54, S56, S66, S67, S73, S82, S89, S91, S94, S107"

Documentary, biography, film, video	10	“S3, S30, S31, S37, S46, S49, S50, S52, S58, S59”
Visualisation, poster preparation, conceptmaps	6	“S10, S15, S23, S28, S38, S45”
Drama	5	“S12, S30, S46, S80, S99”
Cooperativelearning	4	“S17, S29, S46, S48”
Scientific research, project, presentation	13	“S13, S23, S26, S30, S34, S41, S43, S38, S41, S49, S43, S55, S104”
Model-based learning	4	“S9, S36, S87, S97”
Neuroscience subject	1	“S39”
Educational game	1	“S30”
Conceptual change model	4	“S5, S32, S64, S75”
Online discussion	1	“S32”
Stem	3	“S26, S98, S100”
Experiment design, laboratory activity	6	“S20, S65, S70, S83, S92, S101”
Science-Technology-Society Teaching	1	“S21”
FRA-based assignments, FRA wheel	3	“S7, S10, S95”
Socio-scientific subject	6	“S9, S14, S79, S85, S88, S93”
Cooperative teaching	1	“S6
Newspaper articles	2	“S4, S61”
Laboratory trip, communication with scientists	2	“S19, S42
Discourse analysis	1	“S29”
Context-based	1	“S90”
Children's literature	3	“S57, S78, S103”
Problem-based	1	“S76”
Mobile Technology	1	“S69”

When Table 6 is examined, "discussion" in 48 studies, "history of science, historical narrative, history" in 30 studies, "NoS activities" in 29 studies, "reading" in 27 studies, "questioning" in 19 studies, "scientific research, project, presentation" in 13 studies, "documentary, biography, film, video" in 10 studies, "visualization, poster preparation, concept maps" in 6 studies, "experiment design, laboratory activity" in 6 studies, "socio-scientific subject" in 6 studies and "drama" in 5 studies are the most used methods in NoS teaching. Four studies were conducted with "cooperative learning", "model-based learning" and "conceptual change model", three studies each with "Stem", "FRA-based assignments, FRA wheel" and "children's literature", two studies each with "newspaper articles" and "laboratory trip, communication with scientists", methods and techniques. "Neuroscience subject", "educational game", "online discussion", "science-technology-society teaching", "co-

teaching", "discourse analysis", "context-based", "problem-based" and "mobile technology" teaching methods and techniques were preferred once each.

The findings related to the sub-problem "How is the distribution of the assessment tools of the articles on the nature of science?" are presented in Table 7.

Table 7. Distribution of assessment tools used in NoS teaching articles

Assessment Tools	**f**	**Code of Study**
Groupdiscussionreports	7	"S1, S4, S7, S44, S54, S57, S58"
Scientific Epistemological Opinion Scale, Scientific Epistemological Interview Questionnaire, Metacognitive Group Discourse Questionnaire	1	"S2"
VNOS C	19	"S3, S5, S6, S9, S11, S13, S16, S17, S27, S29, S33, S34, S35, S36, S40, S42, S46, S48, S55"
Semi-structured interview form	36	"S3, S5, S6, S15, S16, S17, S22, S24, S27, S30, S34, S35, S36, S37, S38, S40, S41, S45, S48, S49, S51, S56, S61, S63, S64, S67, S71, S75, S77, S79, S86, S89, S91, S92, S96, S98, S106"
Video –audio recordings	13	"S6, S17, S22, S39, S54, S57, S62, S81, S85, S95, S101, S102, S103, S105,"
Reflection papers	10	"S6, S12, S13, S16, S19, S20, S39, S49, S50, S51, S105"
Observation	10	"S15, S16, S17, S22, S55, S71, S75, S76, S92, S107"
SUSSI	9	"S5, S8, S15, S18, S28, S39, S66, S74, S102"
Scale of NOS	1	"S32"
Reflective Drawing Analysis	1	"S10"
Focus group interviews	3	"S12, S32, S92"
NSAAQ	1	"S14"
VNOS-270	3	"S15, S23, S49"
VOSI270	2	"S15, S23"
Student products (drawings/concept maps/notebooks/diary)	6	"S12, S15, S55, S62, S94, S99"
VNOS	11	"S19, S41, S51, S59, S64, S65, S67, S69, S98, S100, S105"
VOSTS	3	"S20, S47, S58"
Worldview Domain Tool	1	"S21"
VNOS-D2	1	"S22"
VNOS B	4	"S24, S25, S78, S81"
Open-ended questionnaire developed by the researcher	22	"S31, S43, S62, S63, S70, S71, S75, S76, S77, S79, S80, S84, S85, S86, S87, S88, S90, S91, S93, S96, S104, S107"
Closed-ended test developed by the researcher	2	"S26, S77"
Nature of Science Questionnaire	1	"S38"
VNOS D	7	"S37, S52, S53, S56, S60, S63, S97"
Survey of RFN	2	"S45, S95"
YCVOS	1	"S72"
SUSSCI	1	"S89"
VASI	1	"S68"

SINOSA	1	"S67"

When Table 7 is analyzed, it is seen that "semi-structured interview form" in 36 studies, "open-ended questionnaire developed by the researcher" in 22 studies, "VNOS C" in 19 studies, "video - audio recordings" in 13 studies, "VNOS" in 11 studies, "reflection papers" and "observation" in 10 studies are the most commonly used assessment tools in NOS articles. In 9 studies "SUSSI" in 7 studies "VNOS D" and in 7 studies "group discussion reports", in 6 studies "student products (drawings/concept maps/notebooks/diary)", in 4 studies "VNOS B", in 3 studies each "focus group interviews", "VNOS-270" and "VOSTS" were used. "VOSI270", "closed-ended test developed by the researcher" and "RFN Questionnaire" were used in two studies each, while 11 assessment tools were included in one study each.

Discussion and Conclusion

In response to the first sub-question, "How is the distribution of studies according to research designs?": it was found that the qualitative research methodology, which included 65 articles, was judged to be the most preferred approach. Twenty-one studies used the quantitative research strategy, while twenty-one studies used the mixed research approach. The nature of science literature recommends using open-ended questionnaires (Lederman, 2007; Schwartz, Lederman, & Crawford, 2004) and interview techniques (Aikenhead, 1988) that allow individuals to explain their own statements with examples in determining their understanding of the nature of science. In fact, these are data collection tools applied to qualitative methods. The use of mixed methods in Nature of Science (NoS) research has increased significantly in recent years. This method aims to provide more comprehensive answers to complex research questions by bringing together both qualitative and quantitative research approaches. Ayvacı and Akdemir (2017) examined 36 master's and doctoral theses and found that the most preferred research approach was the mixed approach, followed by the qualitative approach, and then the quantitative approach. Due to the nature of the research questions, it was stated that it would be useful to complete the missing aspects of the research by using qualitative and quantitative approaches together in theses. According to Ince and Ozgelen's (2015) survey of international journals published between 2004 and 2014, the most popular approach was qualitative, and there was a rise in mixed methodologies. Erdaş, Doğan and Irez (2016) evaluated the reviews which were carried out in Turkey between 1998 and 2012. The review concluded that the studies tended to favor qualitative research approaches. Ocak and Yeter (2018) examined 77 theses and 59 articles on NoS and reached the conclusion that mixed and quantitative methods were the following most popular after qualitative methods. Taşkın (2021) analyzed the articles on the nature of science between 2002 and 2020. According to their findings, the qualitative research approach was the most favored technique, followed by mixed and quantitative techniques. In this study, the author also mentioned that Q-Methodology, a method that was not involved in previous studies, was also included in the studies of articles on NoS, albeit to a lesser extent. Uçer Erdemir and Dinçol Ozgür (2023) reported the abundance of mixed method and quasi-experimental research when they examined the theses made between 2015 and 2021.

According to years, the distribution of the publications on NoS that were studied using the meta-synthesis approach in worldwide indexes. The oldest study scrutinized within the scope of the research is Mejia and Monterola (2015), who examined the constructivist-oriented scientific skills of pre-service teachers in terms of NoS through the metacognitive group. In 2015, the first year analyzed, 14 articles were reached, and in the other years, there was a

slight decrease and increase in the number of articles. Despite this increase and decrease, most of the articles on NoS in scientific education were published in the years 2017, 2018, and 2020. The decrease that has been observed since 2021 could have been brought on by the global COVID-19 issue. Due to the lack of face-to-face education in schools, researchers' orientation towards studies such as literature reviews may have influenced the number of studies on NoS. In addition, the time it takes for a study to be published varies. While some processes progress very quickly, others may take longer. The number of publications may have decreased in 2021-2022 due to the impact of publication processes.

In this research, journals accessed through the Web of Science and EBSCOhost databases were examined. The databases cover a wide range of academic publications across the sciences, social sciences, arts, and humanities. Many publications were discovered when the distribution of articles on NOS was investigated in relation to the journals in which they were published. In total, 41 different academic journals with publications on NoS were accessed, and "Science & Education" was the journal that hosted the highest number of publications in this field with twenty-four publications. "Science & Education" was followed by "International Journal of Science Education" with fifteen publications and "Research in Science Education" with nine publications. There were two journals publishing four studies, three journals publishing three studies, six journals publishing two studies, and twenty-six journals publishing one study. These journals scanned in Web of Science were also scanned in many databases and were scanned in the Social Science Citation Index (SSCI) and Science Citation Index Expanded (SCIE), which are among the indexes sought in terms of academic promotion criteria, the possibility of online access, the popularity of journals in the high quartile for academics (Miranda & Garcia-Carpintero, 2019; Ornek et al., 2021) and the possibility of a high number of citations. The widespread acceptance of WoS in the academic ecosystem (Birkle et al., 2020; Pranckute, 2021) may be the reason for researchers to prefer these journals. 26 journals with one study on NoS and 6 journals with two studies were identified. The publication of different numbers of studies may be related to the focus and scope of the journals or may be the result of the researchers' choice of journals.

The most often examined groups were pre-service teachers, students, and teachers, according to a review of the distribution of articles about NoS by sample/study group. This situation suggests that the researchers preferred to work with pre-service teachers who were already students by choosing an easily accessible sample. It was observed that there were fewer studies conducted with teachers. Behind effective NoS education are teachers that take seriously the significance of NoS learning, as well as their dedication to honestly transmit and faithfully present science to students (Clough, 2018, p.4). It was mentioned in many studies that science teachers have misconceptions about NoS (Adedoyin & Bello, 2017; Garcia-Carmona et al., 2011; Hanson, 2015; Ma, 2009; Onijamowo, 2010; Vazquez-Alonso et al., 2013). Teachers must participate in scientific inquiry activities similar to those used by scientists. This will help them gain a thorough grasp of NoS and how it works, and it will also help students develop enough comprehension (NRC, 2012). Since it is important for pre-service teachers to enhance ideas about NoS, it is thought that it is frequently preferred as a sample. In studies examining NoS research, it has been stated that pre-service teachers are the most preferred group (Ayvacı & Akdemir, 2017; Erdaş, Doğan & Irez, 2016; Murat, 2022; Uçer Erdemir & Dinçol Ozgür, 2023). Ocak and Yeter's (2018) thesis and article evaluations on NOS also led them to the conclusion that undergraduate students were the best sample group. In this study, students were determined to be the second most preferred sample group. It was observed that the majority of the studies were done with secondary school students. It has been shown that many students at all levels of education have naive, static, and confused

views about nature (Dorji et al., 2022). Limited student perceptions of NoS continue to exist (Kine et al., 2020; Kinyota & Rwimo, 2022). It has been determined that middle school and high school students are studied more as samples among student groups. It has been determined that middle and high school students are studied more as samples. Murat (2022) also states that in his study, 8th, 7th, 6th, and 9th grade students were studied as samples after teacher candidates and teachers, respectively. The examination of the understanding of the nature of science of this age group of students based on the suggestions in the literature and the fact that their knowledge of science is higher than that of the lower grades may be the reasons for choosing this sample.

As another result, the sample size of the articles on NoS was analyzed. According to the results of the examination, the most preferred sample size is "21-50" people. Following this came "51-100" and "11-20" people. This result is consistent with the fact of it is the most preferred qualitative research method. In qualitative investigations, fewer participants are needed than in quantitative studies in order to conduct an in-depth analysis. Mixed and quantitative design studies, which include experimental studies with a small number of individuals, can be studies in which groups of 51-100 people are selected as samples. In their study of descriptive analysis of theses in Turkey, Uçer-Erdemir and Dinçol-Ozgür (2023) found that the most studied group of sample sizes was 41-100 people, followed by 11-40 people. Murat (2022) also stated that the most studied groups in articles on NoS between 1999 and 2020 were sample groups of 0-50 people, and that this was compatible with the most preferred qualitative method.

The most preferred teaching approach was the open reflective approach based on the analysis of the distribution of the articles related to NoS according to the NoS teaching approach. According to Clough (2018, p.57), explicit and reflective and highly contextualized NoS teaching plays an important function in NoS teaching by explicitly bringing students' attention to key NoS concerns in scientific curriculum and development. In the open approach, NoS views are developed via set objectives, tests, and feedback for students rather than emerging as a result or adverse impact of inquiry activities (Abd-El-Khalick, 2013). There are many studies in the literature indicating a positive effect or change toward NoS understanding when an open and reflective approach is used in teaching science subjects (Adibelli Şahin & Deniz, 2017; Clough, 2018; Çelik & Bayrakceken, 2012; Piliouras et al, 2017; Khishfe, 2023). In this study, it is seen that the second used is historical; followed by FRA. The historical approach teaches students to appreciate their own ideas after recognizing similarities with those of scientists, and it has an important effect on developing the understanding of NOS (Allchin, 2014; Çen, 2002; Mudavanhu & Zezerwa, 2017; Nur & Fitnat, 2015; Paraskevopoulou & Koliopoulos, 2011; Yücel-Dağ & Taşar, 2016). FRA is a model for conceiving NOS that highlights both contrasts and connections between various "science studies" areas. Since it is a new approach, the number of studies conducted with this approach is low. Kaya and Erduran (2016) defended FRA as a model condenser for NOS concepts. In order to distinguish science from non-science, the family resemblance method employs the categories of inquiry process, aims and value system, social certification and diffusion of scientific information, and societal values (Irzik & Nola, 2011). Due to its function in enabling curricular modification to integrate different ignored components of NoS, the FRA is crucial for both scientific education and science policy makers. The least preferred approach in the studies reviewed is the indirect approach. The indirect NoS teaching approach involves students engaging in scientific research and learning via performing science. This method implies that learning about NoS develops spontaneously as a consequence of participating in inquiry rather than taking into consideration any special interest in or rejection

of NoS activities and experiences. Many studies show that implicit approach is not beneficial for teaching NoS (Bell et al., 2011; Kim & Irving, 2010). As a result, in light of the studies in the literature, researchers seem to have turned to the open-reflective approach.

It was discovered that a broad range of methods and techniques were used after analyzing the distribution of teaching methods and techniques in research on NoS. The approach that was considered to be most favored was "discussion". "Discussion" method was followed by "history of science, historical narrative, history", "and nature of science activities", "reading", "inquiry", "scientific research, project, presentation", "documentary, biography, film, video", "visualization, poster preparation, concept maps", "experiment design, laboratory activity", "socio-scientific subject and drama". Although there is a common belief among scientists that the nature of science should be taught, there is no consensus on the method and technique (McComas & Clough, 2020). In recent years, discussion and argumentation have been reported to be effective methods and approaches in teaching NOS (McDonald, 2017; Oztürk & Uçuş, 2015; Uluçınar-Sağır & Kılıç, 2013). Uçer-Erdemir and Dinçol-Ozgür (2023) stated that 63.11% of the theses on the "Nature of Science" focused on the aim of examining the effect of teaching theory/model/approach/method/technical activities, and the most common one was "the effect of direct reflective approach on views on the nature of science". It is noteworthy that discussion, history of science, nature of science activities, and reading, are more frequently employed due to their positive effects in fostering student engagement, enhancing critical thinking skills and promoting scientific literacy. However, the most suitable technique for effective NoS instruction depends on the age, abilities, and interests of the students, as well as the teacher's resources and infrastructure. Consequently, teachers can utilize a combination of these techniques in a holistic manner to cultivate students' understanding of NoS.

When the distribution of data collection tools in the examined articles is examined, it is seen that the most commonly used interview forms, open-ended question forms and surveys. In the interview forms, the researchers prepared and used the interview form specific to their research. The main reason for this is thought to be the most preferred qualitative research approach and the different criteria they want to determine in the study conducted on a different aspect of the nature of science. The most preferred survey is the VNOS C developed by Lederman, Abd-El-Khalick, Bell and Schwartz (2002). Murat (2022) also reports that survey-scales (VNOS c) were used most as the data collection tool, followed by documents (such as video recordings and concept maps) and interviews. Similar results were found in other studies in the literature (Ayvacı & Akdemir, 2017; Deng et al., 2011; Ocak & Yeter, 2018; Taşkın, 2021; Uçer-Demirer & Dinçol-Ozgür, 2023).

Recommendations

The research covers articles on NoS in the WoS and EBSCOhost databases between 2015 and 2022. The study was limited to 107 articles because of the criteria determined. According to the results obtained, some suggestions are presented below.

- In this study, articles conducted in scientific education on the subject of the NoS were examined and research can be conducted on the basis of different courses.
- Articles were used in the study. The current situation can be analyzed in studies including postgraduate theses and dissertations.
- By expanding the scope beyond the Web of Science and EBSCOhost databases, the trend in NoS teaching studies can be determined.

- In future studies, the themes and variables addressed in teaching NoS can be elaborated.

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