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Representation of Nature of Science in Chemistry Textbooks: Employing Reconceptualized Family Resemblance Approach as a Framework*

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ABSTRACT

One of the important goals of science education is to have scientifically literate people. A proper understanding of the Nature of Science (NOS) is one of the requirements for scientific literacy. Textbooks, which are the concrete materials of curriculars, have an important function in teaching nature of science. The aim of this study is to determine how NOS addressed in the chemistry textbooks according to the publishers of the textbooks, the school types the text books used, and topics in the textbooks. The Reconceptualized Family Resemblance Approach to NOS (RFN), recently offering an alternative framework for nature of science analyses, was used as the framework to analyze the textbooks. Four 9th grade chemistry textbooks which consisted of five chapters and which was published by three different publishers for two different types of high schools were examined. The results showed a total of 419 citations related to NOS, and 335 of them were related to the cognitive-epistemic structure of science while 84 of them were addressed the social-institutional aspect. However, there isn't any single citation related to the political power structures that form the social-institutional aspect of science in the textbooks. In the social-institutional aspect of science, the social values of science were discussed more frequently than other sub-dimensions. More citations were found related to NOS in the textbook, which is taught in science high schools that aims to prepare students to science and technology related professions. The "chemistry as a science field" and "atomic and periodic system", are the first two chapters including more references to NOS. In addition, it was realized that none of the citations explicitly addressed NOS. The results show that a significant effort is needed both in practice and research for teaching the social-institutional aspect in chemistry education as well as in science education.

Keywords: Nature of science, scientific literacy, reconceptualized family resemblance approach, chemistry textbooks, content analysis

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1. INTRODUCTION

One of the main objectives of science education is to have scientifically literate people (AAAS, 1993; DeBoer, 2000; NRC, 1996). Nature of science (NOS) is one of the central components of scientific literacy (Driver, Leach, & Millar, 1996; Laugksch, 2000). Teaching NOS takes place as a goal in science curriculums of many nations around the globe (AAAS, 1993; DeBoer, 2000; McComas & Olson, 1998; Olson, 2018). The Republic of Turkey is a member of many international organizations such as Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS) to improve the merit of education to have scientifically literate and international society integrated people. For this aim science curricula are constantly updated. Many of the objectives of high school chemistry in the updated curriculum by the Ministry of National Education of Turkey (MoNE) are related to NOS (MoNE, 2018). One of the these objectives, which is directly related to NOS, is "*to be able to comprehend nature of scientific knowledge and its development process, which is the common heritage of chemistry and humanity, and the importance of using scientific knowledge in accordance with ethical values*" (MoNE, 2018, p.11).

Learning the NOS aids learners understand the scientific practice, construct informed decisions about socio-scientific problems that we often encounter in modern life, accept science as an important component of modern culture, learn the rules of scientists

* This study was found to comply with the ethical principles of scientific research with the decision numbered 5 taken at the meeting numbered 11, on 21.10.2021 by the Ethics Committee of Social and Behavioral Science Ethics Committee of Atatürk University Institute of Educational Sciences.

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and understand the science (Driver et al., 1996; Leach, Driver, Millar, & Scott, 1997). In the same way, it is stated that integrating the NOS into teaching will help learn of science concepts, improve understanding of science, increase interest in science and ensure that science content is effectively taught for teachers, which will empower them to build informed conclusions (McComas, Almazroa, & Clough, 1998; McComas, 2020).

Although there is an agreement on the necessity of teaching the NOS, it is difficult to say that a complete consensus has been reached on what science and NOS mean. This is due to the dynamic and multi-dimensional structure of science and the scientific process (McComas et al., 1998; Lederman, 2007). Having any exclusive framework for science or for NOS becomes more difficult when science processes including experiment, observation, inference, hypothesis testing, generating laws and theories and many different branches of science (chemistry, physics, biology, astronomy, zoology and many more) are considered (Irzik & Nola, 2011).

The terminology used for the nature of science varies. This concept is expressed in terms such as "applications of science," "science as a way of knowing," "thoughts about science," "how science works" and "the identity and methods of a discipline" (Allchin, 2014). NOS is basically examined by referring to the “epistemology of science”, which examines “the values and beliefs” involved in science and the process of scientific knowledge generation, which is a way of gaining knowledge (Lederman, 1992). The NOS is one of the most common topics in science education research (Lederman, 2007). Although there are many models or approaches about NOS, mostly Consensus View (Lederman, 2007) and recently Family Resemblance Approach (FRA), (Irzik & Nola, 2011) which has recently opened a new perspective in research and teaching of science education, has been the subject for research. In this sense, NOS is mostly defined and examined under different models and approaches such as the Consensus View (Lederman, 2007) and the Family Resemblance Approach (Irzik & Nola, 2011) which has recently opened a new perspective in research and teaching of science education. Each of these models reveals different perspectives on what NOS should encompass and how it should be integrated into science education and teacher education.

Consensus view has been the most adopted and referred approach in science education research for many years for NOS (van Dijk, 2011). According to this approach, there is an agreement between philosophers, scientists and/or science educators on the concept of the NOS, which includes the morals and beliefs involved in the practice in which scientific knowledge is gained and generated (Lederman, 2007; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; McComas, 2004). Main aspects of NOS in the consensus view include scientific knowledge is experimental, inferential, tentative, requiring creativity, intertwined with the culture in which science is made; hypotheses, laws and theories are different kind of knowledge and there isn’t any single scientific method consisting of hierarchical steps as scientific method (Lederman, 1992; Lederman et al., 2002; McComas, 2020)). According to this approach, it is sufficient to teach students only the least controversial aspects of NOS which are widely addressed in philosophy, history and sociology of science, and therefore mentioned in the science education literature. The effectiveness of consensus view on teaching has been examined in many studies in the field (Abd-El-Khalick & Lederman, 2000a; Akerson, Abd-El-Khalick, & Lederman, 2000; Celik & Bayrakceken, 2012; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992).

There have always been disagreements among realists, empiricists, constructivists, feminists and post-modernists, who have different views on science, scientific knowledge, and the scientific process that are what NOS should encompass (Irzik & Nola, 2011). Lederman and his colleagues seem to distinguish NOS from the scientific process skills and they delimit NOS with the values and attitudes that accompany scientific processes (van Dijk, 2011). It is thought that this is not an appropriate approach to address differences between disciplines of science, but that the aims, methods, and methodological rules of science are important components of science and should be included within NOS (Irzik & Nola, 2011).

Recently, the consensus view has continued to receive criticisms that it does not adequately reveal all the features of science (Irzik & Nola, 2011) and that presenting NOS as a list of informed views is not appropriate to comprehend a realistic NOS view (do Nascimento Rocha & Gurgel, 2017). Allchin (2011) states that limiting NOS to a few features in this way is not suitable for functional scientific literacy either. It is also stated that this structure does not solve many dilemmas such as tentativeness and robustness of scientific knowledge and its structure and scientific process; what being influenced from the context more observations or inferences; which terminology is more appropriate law and theory (Hodson & Wong, 2017). In addition, there are many issues that affect NOS, that are not scrutinized by the consensus view such as how social and cultural values effect science. A general representation of NOS is not appropriate to reflect scientific processes and procedures in many different fields of science, and the tenets of NOS presented in the list can be over-simplified by workload-intensive teachers and presented to students in the form of precise and absolute knowledge (Martins & Ryder, 2015; van Dijk, 2011). In the approach where the nature of science is listed in items, the role of financial support, different motivations, refereeing, cognitive biases and ethical violations in the scientific process are also ignored. It is suggested that the current approach should be restructured and modified in a more comprehensive way according to the current perspectives of active scientists, philosophers of science and sociology experts, historians of science (Allchin, 2011, 2017). One of the most important criticisms of this approach is that it ignores the scientific method and process skills (Irzik & Nola, 2011) and it neglects comprehensive and broad perspectives on the relations between science and society and culture (Martins & Ryder, 2015; Matthews, 2016). As a result, there is a necessity to foster a different understanding of NOS represents scientific processes and knowledge and the true diversity of science (van Dijk, 2011).

In this direction, another approach, called Family Resemblance Approach (FRA) has emerged, which is different from the consensus view and has recently gain more popularity. This model was adapted to NOS by Irzik and Nola (2011). Irzik and Nola (2011) state that this approach encompasses all general structural aspects of science with an emphasis on diversity in science and offers a new way of establishing unity in science. According to Erduran and Dagher (2014) it is a great advantage for FRA to allow the use of a wide set of categories that include various characteristics common to all disciplines to characterize a discipline of science. Irzik and Nola (2014) also pointed out that the historic, dynamic and tentative NOS can be revealed by FRA with its unrestricted categories that allow new science features to emerge in each category. FRA is based on the assumption that all disciplines have common features in science, but none of these features alone can be descriptive for all disciplines and these features alone cannot distinguish science from other human activities (Irzik & Nola, 2011).

FRA conceptualizes NOS as a cognitive-epistemic and social-institutional system (see Table 1). While the cognitive-epistemic aspect of science includes practices, aims and values, methods and methodological rules, and scientific knowledge, the social-institutional aspects of science encompasses professional activities, scientific ethos, social certification and dissemination of scientific knowledge, and social values (Erduran & Dagher, 2014; Irzik & Nola, 2014).

Table 1.
NOS for FRA

Science							
Cognitive-Epistemic Aspects				Social-Institutional Aspects			
1	2	3	4	5	6	7	8
Practices	Aims and values	Methods and methodological rules	Scientific knowledge	Professional activities	Scientific ethos	Social certification and dissemination	Social values of science

It is argued that this simple presentation of the approach provides very useful and practical information pedagogically for curriculum development studies and science teaching. (Erduran, Dagher, & McDonald, 2019). To this end, FRA has been reconsidered and expanded in scope to provide a useful framework for organizing science education curriculum and teaching, and to create efficient visual tools to improve individuals' NOS perceptions as Reconceptualized Family Resemblance Approach to NOS (RFN) (Dagher & Erduran, 2016; Erduran & Dagher, 2014). For this purpose, three new categories have been added to the social-institutional aspects of science namely "Social organizations and interactions," political power structures and financial systems. In addition, FRN wheel model was created to show the relationships between cognitive-epistemic aspects and social-institutional aspects that are the two main components of science. In this model, it is aimed to teach NOS in a conceptual and holistic structure rather than teaching its tenets one by one. The model allows teachers, science educators, curriculum developers and textbooks writers to emphasize the relevant NOS component with appropriate topics and concepts (Erduran et al., 2019).

As NOS competence is a necessity in order to have scientifically literate individuals, there are many studies aimed to investigate understandings about the NOS, the factors affecting these understandings (Abd-El-Khalick & Lederman, 2000a; Akgun and Kaya, 2020; Lederman, 1992, 2007; Mihladiz and Dogan, 2017). However, it is reported that neither teachers nor students have reached a sufficient level of competence about NOS despite such efforts (Abd-El-Khalick, & Lederman, 2000; Akgun & Kaya, 2020; Lederman, 1992, 2007, 2013; Ryan & Aikenhead,1992).

Although there are many reasons for the problems experienced about lack of competence about NOS, it is acknowledged that textbooks, which are generally considered mirrors of a science curriculum, have an important role in teaching NOS (Abd-El-Khalick, Waters, & Le, 2008; Chiappetta, Sethna, & Fillman, 1993). However, emphasize on science textbooks on NOS is not as much as in the curricula (Abd-El-Khalick et al., 2017; Ramnarain & Padayachee, 2015). It is even asserted that the biggest obstacle to teach NOS as indicated in the curriculum is science textbooks (McDonald, 2017) because textbooks are used by teachers as the primary source, compared to other teaching material, for organizing their teaching at all education levels (Chiappetta & Fillman, 2007; Krishnamurthy, 2020; Sánchez & Valcárcel, 1999). Sánchez and Valcárcel (1999) determined that 92% of teachers use textbooks as their primary source while making lesson plans. It is seen that teachers mostly benefit from textbooks in classroom activities (Perez & Villagr, 2020). The fact that teachers' and students' misconceptions about NOS were also detected in textbooks demonstrates the role of textbooks in teaching NOS (Irez, 2009). Abd-El-Khalick et al. (2008) state that one of the main reasons for lack of NOS understanding of teachers and students is textbooks, due to the fact that NOS is not given enough importance and Naïve messages about the NOS are included in the textbooks.

There are several studies to determine how the nature of science is addressed by textbooks (Abd-El-Khalick et al., 2008; Chiappetta et al., 1993; Irez, 2009; Niaz & Maza, 2011; Solaz-Portoles, 2010). These studies appear to be largely from the U.S. (Abd-El-Khalick et al., 2017; Abd-El-Khalick et al., 2008; Chiappetta & Fillman, 2007; Niaz & Maza, 2011). In addition, it is seen that the studies that examine the textbooks are largely based on the consensus view that has had an important dominance in NOS literature for years and has recently been criticized (Li et al., 2020; Niaz & Maza, 2011; Ramnarain & Chanetsa, 2016; Solaz-Portoles, 2010). The results show that the textbooks do not properly and adequately reflect NOS (Chiappetta & Fillman, 2007; Esmer, 2011; Irez, 2009; Doğru, Kirbaci, & Çelik, 2021; Li et al., 2020; Ramnarain & Chanetsa, 2016) and this has been continued for years (Abd-El-Khalick et al., 2017; Abd-El-Khalick et al., 2008).

The manner of the NOS represented in textbooks has also been the subject of the literature. These studies (Ford, 2006; McDonald & Abd-El-Khalick, 2017; Abd-El-Khalick, 2002) investigate implicit and explicit representations in textbooks, borrowing the implicit and the explicit terms from studies on teaching NOS (Abd-El-Khalick & Lederman, 2000a; Deng, Chen, Tsai, & Chai, 2011; Duschl & Grandy, 2012). In the implicit approach, it is assumed that NOS will be understood by inquiry teaching activities, learning about the history of science, or offering courses such as philosophy of science or integrating them into science lessons. The crucial difference between the two approaches is whether intentional efforts are made to bring out the NOS and let students reflect on it (Abd-El-Khalick & Lederman, 2000b; Deng et al., 2011). Myriad number of studies reported that clearly emphasizing NOS during these activities is more effective to learn about NOS regardless of what activities are done in teaching (Abd-El-Khalick, 2005; Akerson, Hanson, & Cullen, 2007; Celik & Bayrakceken, 2012; Deng et al., 2011). Studies show that although NOS is addressed in science textbooks, it is usually done in an implicit way rather than explicitly (Aydin & Tortumlu, 2015; Park, Yang, & Song, 2019).

Recently, there have been studies (BouJaoude, Dagher, & Refai, 2017; McDonald, 2017; Park et al., 2019) examined how NOS is addressed in textbooks in accord with the RFN (Dagher & Erduran, 2016). In one of these studies McDonald (2017) investigated how NOS is included within the scope of genetics in four science textbooks in the second grade of middle school in Australia. The results have shown that no explicit emphasis is placed on NOS in the genetics chapter in any of the textbooks examined. Another study using FRA as an analytical framework showed that none of the Lebanese 9th Grade science textbooks was adequately or systematically addressed NOS (BouJaoude et al., 2017). In another study, physics textbooks written based on the new curriculum in South Korea was examined in accord with FRA to find out how NOS is cited. The results have shown that NOS is not reflected in the textbooks, while scientific knowledge, practice, and method, and professional activities of scientists are emphasized, but the social-institutional character of science is not reflected. (Park et al., 2019).

The fact that FRA has come to the forefront in the field NOS teaching and research in recent years, examining how NOS is addressed in textbooks, which have an important role in teaching NOS, according to this approach and making suggestions to educators and publishers in this direction is considered worth investigating (Erduran et al., 2019). However, it is seen that research is limited to above mentioned studies. In addition, it is seen in the studies conducted so far that certain chapters of the textbooks (Abd-El-Khalick et al., 2017; McDonald, 2017) were selected for analysis. In this sense, all chapters of biology textbooks were analyzed by only one study (Chua, Tan, & Ramnarain, 2019). In this study, it is aimed to examine all the chapters instead of any chapter of the selected chemistry textbooks to see how NOS is represented throughout the textbooks. The results are expected to contribute to the formation of understanding about which dimensions of NOS would be more appropriate to associate with which content.

Consequently, the goal of this study is to investigate how NOS is represented in 9th grade high school chemistry textbooks, in accord with the RFN, and how this changes according to the publishers, book chapters/topic and the types of high schools the textbooks used.

1.1. Statement of the Problem

The following questions are pursued in the study:

- How is NOS depicted in high school freshman chemistry textbooks in accord with the RFN?
- Which dimensions of the nature of science are addressed more in the chemistry textbooks by the chapters?
- How does the nature of science citations changes in the chemistry textbooks by school types?

2. METHODOLOGY

The study was planned and carried out based on the document analysis approach, which is one of the qualitative research approaches. Document analysis is an approach used in the analysis and evaluation of written and electronic documents in order to create insights and reveal meanings (Bowen, 2009; Patton, 1990). This study was carried out in order to investigate determine how NOS is addressed in high school first grade chemistry textbooks according to the RFN (Dagher & Erduran, 2016). Descriptive analysis method (a deductive content analysis) which is one of the qualitative analysis methods was employed to analyze the textbooks. With the method of content analysis, the comprehensive texts are summarized under codes, categories and themes (Krippendorff, 2018).

Wang (1998) suggests determining a conceptual framework for content analysis, conducting the analysis by more than one researcher, avoiding the selection of only a particular chapter or unit within the book, and making clear definitions for the analysis units for the consistency of the analysis.

In this study, the RFN structure was used as an analysis framework to examine textbooks. This structure provides a suitable analytical framework to reveal the NOS elements in textbooks (Erduran & Dagher, 2014). The content of the textbooks is coded according to the nature of the science described in the RFN structure. Instead of selecting only a certain chapter from the books, the whole textbook was analyzed in this study.

In order to ensure consistency in the analysis, what is meant by each dimension that constitutes the FRA structure was clearly stated and sample analyzes were made from the books to provide guidance in the analysis. Definitions were used for each dimension that constitutes the FRA structure that constitutes the analysis units. In addition, in order to ensure the reliability, the analysis was carried out in cooperation with the two researchers. For this, all the books were coded by the first researcher using a qualitative analysis software according to the dimensions of the RFN structure. Later, these encodings were examined by the two researchers together and the detected discrepancies were resolved by discussing on each discrepancies.

In the study, four textbooks certified and taught by the Ministry of National Education (MoNE) in Turkey were examined. Instead of choosing a random unit or chapter in the textbooks or purposefully selecting a chapter that are expected to address NOS more, all four textbooks have been examined. In the chemistry curriculum (MoNE, 2018), it is recommended to teach the nature of science by associating it with the relevant content throughout the course.

The study was found to comply with the ethical principles of scientific research with the decision numbered 5 taken at the meeting numbered 11, on 21.10.2021 by the Ethics Committee of Social and Behavioral Science Ethics Committee of Atatürk University Institute of Educational Sciences.

2.1. Examined Textbooks

In Turkey, MoNE determines required qualifications, prepares, examines, publishes, and distributes the textbooks to the schools. MoNE also determine the qualifications to be found in publishing houses (MoNE, 2015). Two of the selected textbooks were published by the MoNE and the other two were published by private publishers. One of the textbooks published by the MoNE was prepared to be taught in regular high schools and the other one in Science High Schools throughout the country. Two books published by private publishing company were published to be taught in regular high schools across the country. A professor served as editor in each of the books published by MoNE. Four chemistry teachers authored one of the textbooks and three teachers for the other one. A language, a curriculum development, an assessment and evaluation, a school counseling, a visual and graphics design specialist took part in the writing process of these textbooks. The textbooks published by private companies were written by a single author and only one language and one visual design expert were employed. All accredited textbooks regardless of publishers are distributed all students at public school for free of charge. Only one of these books is distributed to each school. As seen in Table 2, the textbooks published either 2018 or 2019 and page range from 208 to 223.

Table 2.
Examined Chemistry Textbooks

	Textbook Name	Publisher	Authors	Edition	Publication Year	Page numbers
Textbook-A	9th Grade Chemistry Textbook	Evrensel Iletisim Press	1	1	2018	218
Textbook-B	9th Grade Chemistry Textbook	MoNE Press	3	2	2019	221
Textbook-C	9th Grade Chemistry Textbook	Sonuc Press	1	1	2018	223
Textbook-D	9th Grade Science School Chemistry Textbook	MoNE Press	4	1	2019	208

As seen in Table 3, the organization of the chapters and the topics in the chapters are the same for all of the chemistry textbooks. Each of the chemistry textbooks consists of five chapters: atomic and periodic system, interactions between chemical species, states of matter, nature and chemistry.

Table 3.
The Chapters and Associated Page Numbers of the Textbooks

Chapter	Chapter Title	Number of Topics	Number of pages
1	Chemistry as a Field of Science	4	48, 49, 44, 58
2	Atom and Periodic System	3	42, 42, 42, 44
3	Bonding and chemical Reactions	5	48, 48, 52, 38
4	States of Matter	5	42, 40, 50, 36
5	Nature and Chemistry	2	38, 41, 33, 32

2.2. Turkish Educational System

There is a twelve-year compulsory education segmented into three four-year long programs. The first quadruple is called primary school, the second is called middle school and the last quadruple-years is called high school. High school is defined as a secondary education institution with at least four years long training, which educates students between the ages of 14 and18 for higher education. There are eleven types of high schools in the Turkish education system. While the students attend these high schools, they are assigned the chemistry textbooks seen in Table 2 in the 9th grade. The students who attend to Science High Schools, which is one of the high school types, are taught by a Science School 9th Grade Chemistry Textbook. Students who

are interested in a profession related to science and technology prefer the Science High Schools. Students who want to go these kinds of high schools are selected at the end of the 8th grade through a nationwide examination (MoNE, 2015b).

Science-related courses, which are compulsory for all students, start in the fourth grade and go on by the end of ninth grade. The science courses offered by nineth grade are given under the name of science, without being separated as independent courses by discipline of chemistry, physics and biology. In the first year of high school education, namely in the 9th grade, science lessons are offered to all students as discipline specific including chemistry, physics and biology for the first time. In the 9th grade, chemistry, physics and biology courses are compulsory to prepare all individuals for the future as scientifically literate. In this study, 9th grade chemistry textbooks were chosen for this reason.

Reform studies have been continuing since 2005 by MoNE within the scope of the vision of raising scientifically literate individuals in curricula at all levels. In this context, the high school chemistry curriculum has been updated three times; in 2007, 2013 and 2018 respectively.

3. FINDINGS

In this section, the results about how the NOS is represented in the chemistry textbooks that are subjected to content analysis according to the RFN are presented separately according to the textbooks and the chapters in the books.

Table 3.
Excerpt Showing Coding from the Chemistry Textbooks Based on the RFN

NOS Dimensions	**Excerpts from the textbooks**
1.1. Aims and values	Science is on a quest for simplicity. Although the complexity of the world seems to be infinite, there is a simplicity underlying this complexity that science is trying to discover. Chemistry's contribution to discovery is to show how everything in the environment is composed of simple units (Textbook-C, Chapter 1, p. 45).
1.2. Practices	Boyle systematically investigated the behavior of gases in quantitative aspect, conducting a series of experiments about the pressure-volume relationship of a gas sample. Today, the relation where the pressure of a gas is inversely proportional to its volume at a constant temperature is known as "Boyle's Law" (Textbook-C, Chapter 1, p.20).
1.3. Methods and Methodological rules	All atomic models are views put forward through various scientific studies and experiments. After an atomic model was developed, it remained valid for a while, but as a result of new scientific findings, it was replaced by another atom model (Textbook-A, Chapter 2, p. 51).
1.4. Scientific knowledge	While explaining the concepts of chemistry, laws, theory and models are used (Textbook-D, Chapter 2, p.67).
2.1. Professional activities	Nearly 300 scientific articles of Aziz SANCAR have been published and with more than 12,000 references to these articles, he has achieved an unprecedented success in scientific research (Textbook-D, Chapter 4, p. 131).
2.2. Scientific ethos	One of the responsibilities of scientists and people conducting scientific research is to respect the work of other people or groups who have done research on the same or similar subject and to maintain these attitudes during the writing and publication process (Textbook-C, Chapyer-5, p.205).
2.3. Social certification and dissemination	A symbol systematic for elements was first proposed by J. J. Berzelius in 1814. The symbolic representation of the elements proposed by Berzelius and accepted in the scientific community is still in use today (Textbook-A, Chapter 1, p. 29).
2.4. Social values of science	The major factor in the birth and advancement of all natural sciences is meeting the basic needs of people. Matter is used while meeting these basic needs. Chemistry has come to the fore in order to understand the structure of the matter and to synthesize new substances (Textbook-D, Chapter 1, p.17).
2.5. Social organization and interactions	Chemists depend on their skills to communicate effectively and creatively in a scientific, social and cultural sense in their native language so that they can work efficiently in their workplaces, solve problems and take responsibility to lead. There are many industrial areas that fall under the field of chemists' work. Pharmaceuticals, fertilizers, petrochemicals, waste treatment and dye-textile are the main areas of these fields (Textbook-C, Chapter 1, p.23).
2.6. Political power structures	-
2.7. Financial systems	After this period, he went to the U.S. to do his doctorate with the TUBITAK scholarship and continued his education in Texas University in Dallas (Textbook-A, Chapter 3, p.124).

As seen Figure 1, a total of 419 citations were identified to NOS in all textbooks. It was found that 335 of these citations were related to the cognitive-epistemic structure of science and only 84 of them were related to the social-institutional structure of science. None of these explicitly emphasizes any dimensions of the nature of science. Accordingly, it is seen that the cognitive-epistemic dimensions of science are more cited compared to the social and institutional dimensions at all textbooks. It has been determined that the scientific practices dimension, which is one of the dimensions that constitute the cognitive and epistemic structure of science, is cited the most among all dimensions. On the other hand, it is seen that within the dimensions that make up the social and institutional structure of science, which is less widely covered in the books, the social values of science are cited the most in the books compared to the other sub-dimensions. The textbook used by science schools preferred by students who are interested in science and technology related professions has more citations to NOS when compared to other three textbooks. Another striking finding is none of the citations to NOS was explicit, but rather implicit.

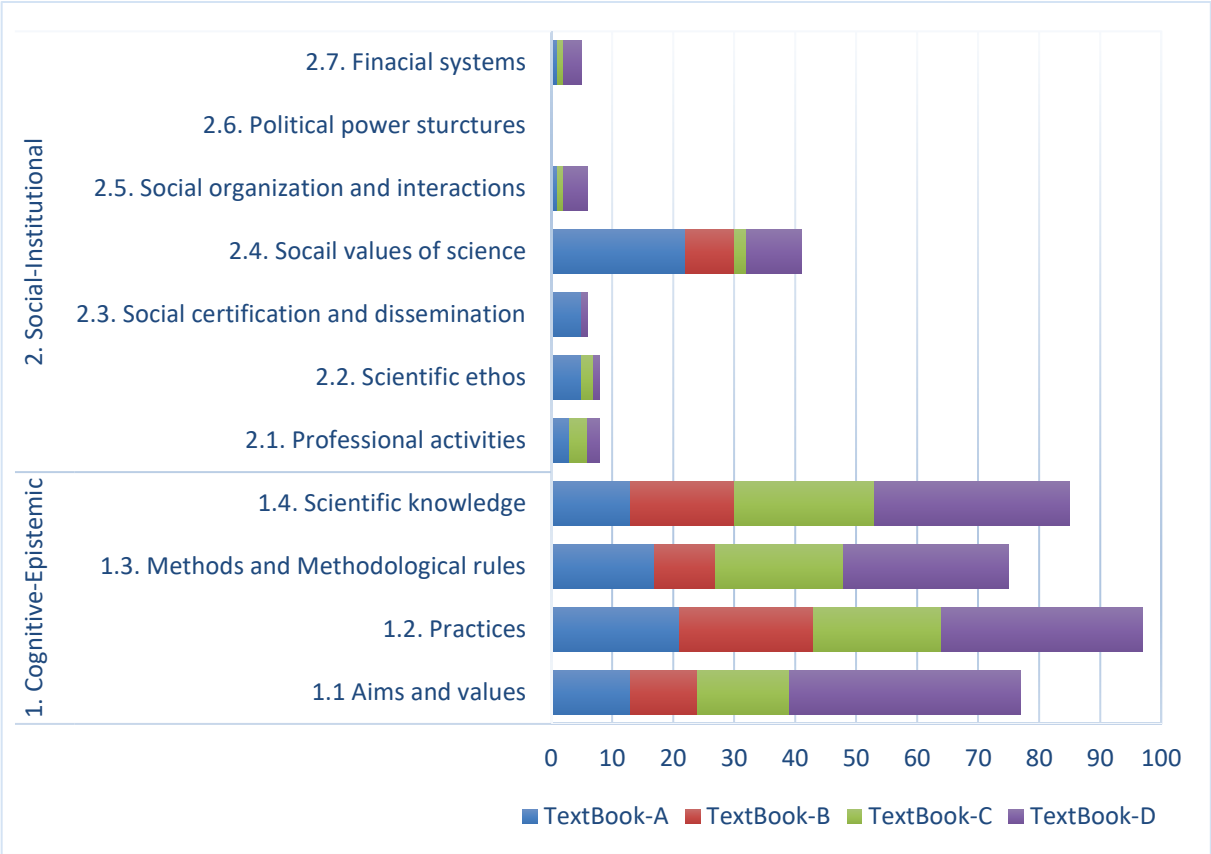

Figure 1. The number of citations to NOS dimensions in the textbooks

In the reviewed textbooks, references are made to the concepts of empirical competence, explanatory power, objectivity and prediction in terms of aim and values aspect of NOS. In the scientific practices dimension, it is seen that while experimentation, observation, measurement and classification skills are emphasized more, there is also few emphases on analytical skills including logical thinking. Similarly, there is more citations to observational data in the scientific methods and methodological rules sub-dimension while there are much less citations to analytical methods. Few citations are placed on the tentative nature of scientific knowledge. The second most cited sub-dimension in the textbooks is the scientific knowledge following practices dimension. Although scientific theory, law, hypothesis and models are frequently used in the textbooks, the nature of these concepts and their relationship with each other is not mentioned sufficiently. As can be seen in the example excerpt given in Table 3, it is stated that the theory, laws and models in chemistry aim to explain the concepts in chemistry as a system in the only excerpt in the examined textbooks.

On the other hand, the contributions of science to social life in the context of the social-institutional structure of science are cited a lot in the chemistry textbooks. Book-A has numerous references to this dimension. Under this dimension, the contributions of science especially to human life are mentioned. In this sense, the relationship between chemistry and technology was mentioned many times especially in the first and the last chapters (see Fig. 2). References to other aspects of NOS are mostly made in short biographies of the Turkish Nobel Laureate and scientist Aziz Sancar that purposefully integrated into high school chemistry curriculum.

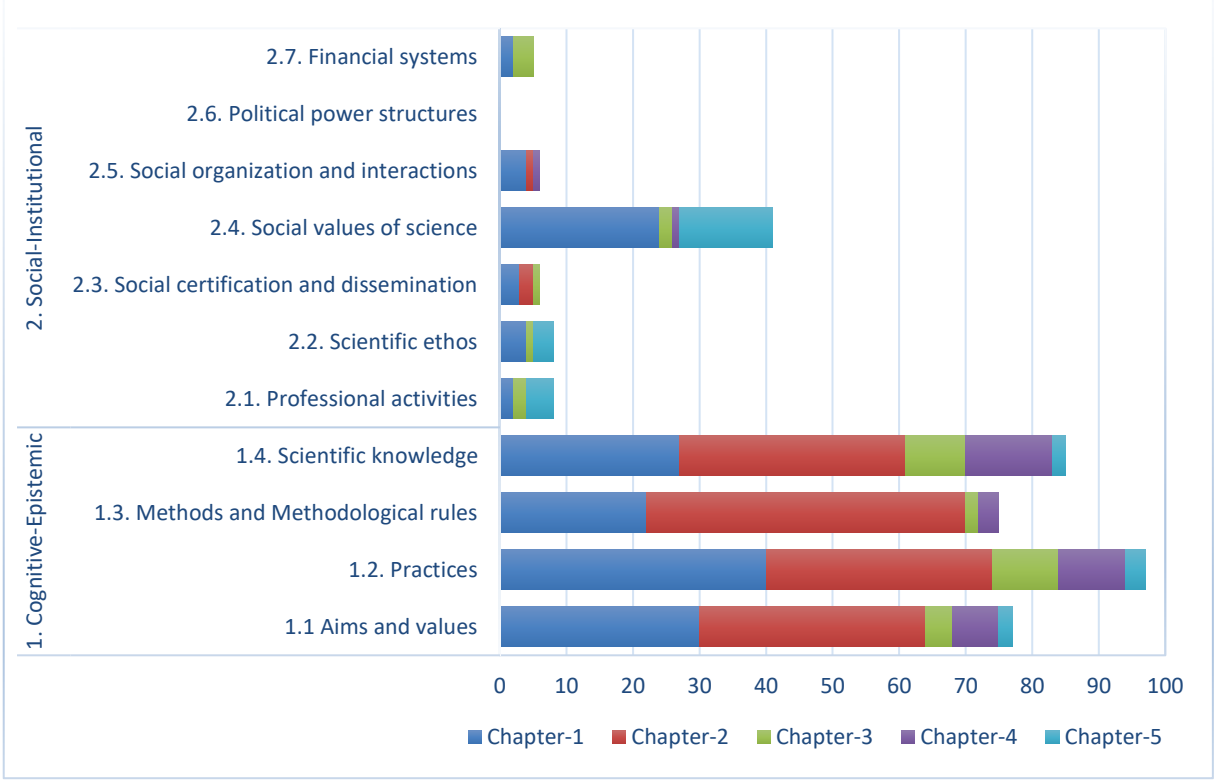

Figure 2. The number of citations for NOS tenets in the textbooks by chapters

When the citations to NOS were examined by chapters and topics in the chemistry textbooks, it is seen that more references are made to NOS in the first and second chapters compared to the rest as seen in Figure 2. The main topic of the first chapter is related to "chemistry as a field of science" which focuses on history of chemistry and development of chemical processes. The second chapter is related to "atom and periodic system" which emphasizes on development of atom concept and periodic table of elements. When the citations to NOS in these chapters are compared, it is seen that more citations are made to NOS in the chapter of "atom and periodic system." It has been found that very few references are made in other chapters in the textbooks. However, the social and institutional aspects of NOS is relatively cited most by chapter five.

4. RESULTS, DISCUSSION AND RECOMMENDATIONS

The purpose of this study is to determine how NOS is addressed in high school chemistry textbooks written after the reforms carried out in high school chemistry curricula and how citations to NOS differ across the chapters and topics of these textbooks. The textbooks were analyzed in accord with RFN. The results showed that a total of 419 times NOS was addressed in four chemistry textbooks examined, 335 of which were related to the cognitive-epistemic aspect of NOS and only 84 of which were related to the social and institutional aspect of NOS. In the cognitive-epistemic structure of science, more references have been made to the practices dimension. The textbook that is designed for science high schools where students with more aspiration in science and related professions addressed NOS more than the other three textbooks. In the chapters that make up the books, there are more references to the nature of science in the first chapter (Chemistry as a field of science) and in the second chapter (atom and periodic system). The references to NOS were also examined whether they are explicit or implicit. It appears that none of the identified citations was explicitly addressed NOS and its tenets. It is also evident in other studies in the literature (Abd-El-Khalick et al., 2017; Abd-El-Khalick et al., 2008; Aydin & Tortumlu, 2015; Chua et al., 2019; Li et al., 2020; Marniok & Reiners, 2016; Upahi, Ramnarain, & Ishola, 2020). This demonstrates that despite all the reform efforts in science and especially chemistry curriculum, the textbooks lack in quantity and quality in terms of NOS.

Similar to previous research examined how textbooks address NOS based on the RFN, cognitive-epistemic aspect of NOS is cited more than social aspects of NOS. The cognitive-epistemic aspects of science include scientific practices, scientific methods and rules, aims and values, and scientific knowledge dimensions (BouJaoude et al., 2017; Park et al., 2019). In contrast, less reference has been made to the social aspect of science. It has been determined that the dimensions of scientific practices have the largest footprint in the textbooks regarding NOS.

Among the dimensions that constitute the social-institutional nature of science, the dimension of the contribution of science to social life was addressed the most similar to findings of BouJaoude et al. (2017). However, for an adequate understanding of NOS, both the social-institutional and cognitive-epistemic aspects of science should be addressed (Fuselier, Jackson, & Stoiko, 2016). There have been studies that investigated to what extent the nature of science is included in certain topics that allow teaching NOS through the history of science, such as the periodic system (Niaz & Maza, 2011). In this study, it is seen that there are more references to NOS in the chapter of periodic system. This result supports the idea that there is a tendency to include

NOS in certain topics, especially in the first chapters of the books such as chemistry as science field, atom, and periodic system (Abd-El-Khalick et al., 2008; Aydin & Tortumlu, 2015; Upahi et al., 2020). In these chapters, it is seen that the nature of science is integrated into topics by case studies about scientists' work, especially in the history of science. Chua et al. (2019) claimed that the topics related to the history of science have more citations to NOS. Considering that students focus less on these non-chemistry chapters (Chua et al., 2019), only referring to the nature of science in these chapters will make it difficult to pass on the subject-content units in terms of the nature of science. In addition, in order to create a realistic understanding of NOS, it is necessary to address NOS not only in a few chapters (MoNE, 2018) but rather across the chemistry curriculum that might be reflected to chemistry textbooks. In other words, curricula should include specific content objectives that directly and explicitly address NOS so that they might find a place in related textbooks.

People who complete compulsory education should have certain level of competence in NOS, to become scientific literate as one of the aims of the compulsory education (DeBoer, 2000; Laugksch, 2000). For this reason, science lessons are obligatory for all students at certain stages of the compulsory education. However, in this study, it was determined that there is a difference in the references to the nature of science in different school types in the chemistry textbooks that are taught to all students in their first year at high school. It was observed that the chemistry textbook used in science high schools, which preferred by the students especially interested in science and technology-related professions, addressed NOS more than other textbooks used by the other high school types. This result may imply that the authors of the science school chemistry textbook may have a prevailing understanding that knowledge of NOS is a necessity for those working in science and technology related professions, especially for scientists.

One of the results of the study shows that some chapters of the textbooks address to certain aspects of NOS not the other aspects. It is seen that while chapter one in all the textbooks cites almost all aspects of NOS, the other chapters, especially the fourth and fifth, many dimensions of NOS are not cited at all. This shows that the dimensions of the nature of science that constitute RFN can be addressed independently in textbooks (McDonald, 2017). Erduran et al. (2019) claimed this as a superiority of RFN.

It is known that when the political and financial aspects, which are part of the social- institutional tenets of NOS, are included in science courses, students' participation in science classes increases. Thus, these aspects of scientific activity should be aware of by individuals for scientific literacy (Erduran & Dagher, 2014). However, it is reported that no reference is made to ethics, financial systems and political power structures of science in textbooks (Park et al., 2019). Similarly, it was determined that not a single reference is made to the nature of political power structures of science in any of the examined textbooks. While few references are made to other dimensions that constitute the social-institutional aspect of science, the fact that no reference has been made to this dimension is not appropriate to have a sound understanding about real science practice. It is a well-known fact that political power structures have greatly influenced scientific research activities (Erduran & Dagher, 2014). It is inevitable for youngsters who is trained to be scientifically literate individuals with a realistic understanding of science to be negatively affected by neglecting this dimension of science in chemistry teaching. Erduran and Dagher (2014) also stated that it is important for students to have a realistic understanding of science about how scientific knowledge is generated, used and even distorted many times for different purposes. Regardless this importance, the reason of why the textbooks do not even implicitly address the political power structure would be due to how curriculum developers and textbook authors perceived science or NOS. It seems that they have an informed common view about science rather than more comprehensive view based on RFN. It is very crucial as new perspectives would be sought by the experts in the field to update science curriculum in general and chemistry curriculum in particular (Kaya & Erduran, 2016).

When the high school chemistry curriculum is examined, it was found that there were overarching objectives address NOS as general purpose (Ağlarcı Özdemir, 2021). But, there are few objectives in the curriculum that is placed mostly in the first two chapters directly mentioned NOS which would be the reason why related chapters of the textbooks cover most of the NOS citations of all. It means that the textbook authors would like to have direct objectives to guide them how to addressed NOS otherwise they would most probably not place NOS in the books even though overarching objective of the curriculum mentioned it. Although there are limited references to the social-institutional aspect of NOS, it is seen that case studies from both the history of science and the lives of scientists today are used to address this aspect. Especially a short biography and studies of Turkish-American Nobel Chemistry Laurate Aziz Sancar is used as a context to address the social-institutional aspects of science including professional activities of scientists, the acceptance and publication of scientific knowledge, and social structures and interactions in the field of science. In addition, the financial resources of science, which is one of the dimensions of the social-institutional aspect of science, have been mentioned through grants provided by the Scientific and Technological Research Council of Turkey to both scientists and students at different education levels. Erduran and Dagher (2014) pointed out that these dimensions of NOS can be highlighted by referring to the support provided for science and technology projects at national and local scale, and science project competitions organized for students.

Similar to this study, the related literature also reported that especially the social-institutional aspects of science are not sufficiently covered in the curriculums (Kaya, & Erduran, 2016) and in textbooks (BouJaoude et al., 2017; Park et al., 2019). Considering that books are one of the resources used extensively by teachers and students in science education, this situation will negatively affect the construction of a realistic science understanding of both students and teachers. It is stated that this deficiency in the books is mostly caused by the book authors (Li et al., 2020; Ramnarain & Chanetsa, 2016). However, high school

science and chemistry textbooks are written predominantly by science educators and teachers. In order to overcome this issue, the social-institutional aspect of NOS should be integrated more in both teacher education and science education.

One of the appropriate methods for teaching the social-institutional dimension of science to teachers and students in a realistic way may be introducing prospective teachers and students to scientists and scientific societies conducting scientific research and visiting research centers. Conversations with scientists, their sample publications, their projects, research groups and working environments, information about the scientific congresses and meetings they attended, and examples of communication and interaction between scientists in these meetings can be included in the textbooks. In addition, the institutions from which scientists receive support for scientific research and the mechanisms of these supports should be included in the textbooks, and the dimensions of political power structures and financing of science related to the social-institutional aspect of science should be addressed.

Research and Publication Ethics Statement

This study was found to comply with the ethical principles of scientific research with the decision numbered 5 taken at the meeting numbered 11, on 21.10.2021 by the Ethics Committee of Social and Behavioral Science Ethics Committee of Atatürk University Institute of Educational Sciences.

Contribution Rates of Authors to the Article

The authors contributed equally to the article.

Statement of Interest

There is no conflict of interest in this study.

5. REFERENCES

American Association for the Advancement of Science (AAAS), Project 2061. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: the impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education, 27*(1), 15-42.

Abd-El-Khalick, F. (2002). Images of nature of science in middle grade science trade books. *New Advocate*, *15*(2), 121–127.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: A critical review of the literature. *International journal of science education*, *22*(7), 665-701.

Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers' conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057-1095.

Abd-El-Khalick, F., Myers, J. Y., Summers, R., Brunner, J., Waight, N., Wahbeh, N., ..., & Belarmino, J. (2017). A longitudinal analysis of the extent and manner of representations of nature of science in US high school biology and physics textbooks. *Journal of Research in Science Teaching, 54*(1), 82-120.

Abd-El-Khalick, F., Waters, M., & Le, A. P. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching, 45*(7), 835-855.

Ağlarcı Özdemir, O. (2021). 2018 Ortaöğretim kimya dersi öğretim programlarinin fen liseleri ve diğer lise türleri açisindan incelenmesi. *Uludağ Üniversitesi Eğitim Fakültesi Dergisi* , 34 (1) , 84-124 .

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317.

Akerson, V. L., Hanson, D. L., & Cullen, T. A. (2007). The influence of guided inquiry and explicit instruction on K–6 teachers' views of nature of science. *Journal of Science Teacher Education, 18*(5), 751-772.

Akgun, S., & Kaya, E. (2020). How Do University Students Perceive the Nature of Science? *Science & Education, 29*(2), 299-330.

Allchin, D. (2011). Evaluating Knowledge of the Nature of (Whole) Science. *Science Education, 95*(3), 518-542.

Allchin, D. (2014). From Science Studies to Scientific Literacy: A View from the Classroom. *Science & Education, 23*(9), 1911-1932.

Allchin, D. (2017). Beyond the Consensus View: Whole Science. *Canadian Journal of Science Mathematics and Technology Education, 17*(1), 18-26.

Aydin, S., & Tortumlu, S. (2015). The analysis of the changes in integration of nature of science into Turkish high school chemistry textbooks: is there any development? *Chemistry Education Research and Practice, 16*(4), 786-796.

BouJaoude, S., Dagher, Z. R., & Refai, S. (2017). The portrayal of nature of science in Lebanese ninth grade science textbooks. In *Representations of Nature of Science in School Science Textbooks* (pp. 79-97).

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2), 27-40.

Celik, S., & Bayrakceken, S. (2012). The Influence of an Activity-Based Explicit Approach on the Turkish Prospective Science Teachers' Conceptions of the Nature of Science. *Australian Journal of Teacher Education, 37*(4), 75-95.

Chiappetta, E. L., & Fillman, D. A. (2007). Analysis of five high school biology textbooks used in the united states for inclusion of the nature of science. *International Journal of Science Education, 29*(15), 1847-1868.

Chiappetta, E. L., Sethna, G. H., & Fillman, D. A. (1993). Do Middle School Life-Science Textbooks Provide a Balance of Scientific Literacy Themes. *Journal of Research in Science Teaching, 30*(7), 787-797.

Chua, J. X., Tan, A. L., & Ramnarain, U. (2019). Representation of NOS aspects across chapters in Singapore Grade 9 and 10 Biology textbooks: insights for improving NOS representation. *Research in Science & Technological Education, 37*(3), 259-278.

Dagher, Z. R., & Erduran, S. (2016). Reconceptualizing the Nature of Science for Science Education. *Science & Education, 25*(1), 147-164.

Dagher, Z. R., & Erduran, S. (2016). Reconceptualizing the Nature of Science for Science Education. *Science & Education, 25*(1), 147-164.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching, 37*(6), 582-601.

Deng, F., Chen, D. T., Tsai, C. C., & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95*(6), 961-999.

do Nascimento Rocha, M., & Gurgel, I. (2017). Descriptive Understandings of the Nature of Science: Examining the Consensual and Family Resemblance Approaches. *Interchange, 48*(4), 403-429.

Driver, R., Leach, J., & Millar, R. (1996). *Young people's images of science*: McGraw-Hill Education (UK).

Duschl, R. A., & Grandy, R. (2012). Two views about explicitly teaching nature of science. *Science & Education*, 1-31.

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories* (Vol. 43): Springer.

Erduran, S., Dagher, Z. R., & McDonald, C. V. (2019). Contributions of the Family Resemblance Approach to Nature of Science in Science Education. *Science & Education, 28*(3-5), 311-328.

Esmer, F. (2011). Exploring representation of nature of science aspects in 9th grade chemistry textbooks (Unpublished master's thesis). Middle East Technical University, Ankara.

Ford, D. J. (2006). Representations of science within children's trade books. *Journal of Research in Science Teaching*, *43*(2), 214-235.

Fuselier, L. C., Jackson, J. K., & Stoiko, R. (2016). Social and Rational: The Presentation of Nature of Science and the Uptake of Change in Evolution Textbooks. *Science Education, 100*(2), 239-265.

Hodson, D., & Wong, S. L. (2017). Going beyond the consensus view: Broadening and enriching the scope of NOS-oriented curricula. *Canadian Journal of Science, Mathematics and Technology Education, 17*(1), 3-17.

Irez, S. (2009). Nature of Science as Depicted in Turkish Biology Textbooks. *Science Education, 93*(3), 422-447.

Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education, 20*(7-8), 591-607.

Irzik, G., & Nola, R. (2014). New directions for nature of science research. In *International handbook of research in history, philosophy and science teaching* (pp. 999-1021): Springer.

Kaya, E., & Erduran, S. (2016). Yeniden kavramsallaştırılmış "aile benzerliği yaklaşımı": Fen eğitiminde bilimin doğasına bütünsel bir bakış açısı. Part B: Türk Fen Eğitimi Dergisi, 3(2), 77-90.

Khishfe, R., & Abd-El-Khalick, F. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39*(7), 551-578.

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*: Sage publications.

Krishnamurthy, S. (2020). The future of business education: A commentary in the shadow of the Covid-19 pandemic. *Journal of Business Research, 117*, 1-5.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education, 84*(1), 71-94.

Leach, J., Driver, R., Millar, R., & Scott, P. (1997). A study of progression in learning about 'the nature of science': Issues of conceptualization and methodology. *International Journal of Science Education, 19*(2), 147-166.

Lederman, N. G. (1992). Students and Teachers Conceptions of the Nature of Science - a Review of the Research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In *Handbook of research on science education* (Vol. 2, pp. 831-879).

Lederman, N. G. (2013). Nature of science: Past, present, and future. In *Handbook of research on science education* (pp. 845-894). Routledge.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Li, X. Y., Tan, Z. Y., Shen, J. L., Hu, W. P., Chen, Y. H., & Wang, J. Y. (2020). Analysis of Five Junior High School Physics Textbooks Used in China for Representations of Nature of Science. *Research in Science Education, 50*(3), 833-844.

Marniok, K., & Reiners, C. S. (2016). The Representation of Nature of Science in German School Chemistry Textbooks. *Chemkon, 23*(2), 65-70.

Martins, A. F. P., & Ryder, J. (2015). *Nature of Science in science education: a proposal based on 'themes'.* Paper presented at the Proceedings of the GIREP-MPTL 2014 International Conference.

Matthews, M. R. (2016). Reconceptualizing the nature of science for science education. *Studies in Science Education, 53*(1), 105-107.

McComas, W. F. (2020). Principal elements of nature of science: Informing science teaching while dispelling the myths. In Nature of science in science instruction (pp. 35-65). Springer, Cham.

McComas, W. F. (2004). Keys to Teaching the Nature of Science. *Science Teacher, 71*(9), 24-27.

McComas, W. F., & Olson, J. K. (1998). The nature of science in international science education standards documents. In *The nature of science in science education* (pp. 41-52): Springer.

McComas, W. F., Almazroa, H., & Clough, M. P. (1998). The Nature of Science in Science Education: An Introduction. *Science & Education, 7*(6), 511-532.

McDonald, C. V. (2017). Exploring representations of nature of science in Australian junior secondary school science textbooks: A case study of genetics. In *Representations of Nature of Science in School Science Textbooks* (pp. 98-117): Routledge.

McDonald, C. V., & Abd-El-Khalick, F. (2017). Where to from here? Implications and future directions for research on representations of nature of science in school science textbooks. In *Representations of Nature of Science in School Science Textbooks* (pp. 215-231). Routledge.

Mihladiz, G., & Dogan, A. (2017). Investigation of the pre-service science teachers' pedagogical content knowledge about the nature of science. Hacettepe Universitesi Egitim Fakultesi Dergisi-Hacettepe University Journal of Education, 32(2), 380-395.

Ministry of National Education (MoNE). (2015a). *Millî eğitim bakanlığı ders kitapları ve eğitim araçları yönetmeliği.* Retrieved from http://mevzuat.meb.gov.tr/html/dersarac/dersarac.html on 12 February 2021.

Ministry of National Education (MoNE). (2015b). *Türk Eğitim Sistemi ve Ortaöğretim,* Ministry of Education Publishing Retrieved from http://ogm.meb.gov.tr/meb_iys_dosyalar/2017_06/13153013_TES_ve_ORTAYYRETYM_son10_2.pdf

Ministry of National Education (MoNE). (2018). Ortaöğretim Kimya Dersi Öğretim Programı. Retrieved from http://mufredat.meb.gov.tr/ProgramDetay.aspx?PID=350.

Niaz, M., & Maza, A. (2011). Nature of science in general chemistry textbooks. In *Nature of science in general chemistry textbooks* (pp. 1-37). Springer, Dordrecht.

NRC. (1996). *National science education standards*. (0309053269). National Academy Press.

Olson, J. K. (2018). The Inclusion of the Nature of Science in Nine Recent International Science Education Standards Documents. *Science & Education, 27*(7-8), 637-660.

Park, W., Yang, S., & Song, J. (2019). When Modern Physics Meets Nature of Science The Representation of Nature of Science in General Relativity in New Korean Physics Textbooks. *Science & Education, 28*(9-10), 1055-1083.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*: SAGE Publications, inc.

Perez, S., & Villagr, J. A. M. (2020). The learning activities included in the textbooks of Nature Sciences and the development of scientific competences. *Revista Eureka Sobre Ensenanza Y Divulgacion De Las Ciencias, 17*(2).

Ramnarain, U., & Chanetsa, T. (2016). An analysis of South African Grade 9 natural sciences textbooks for their representation of nature of science. *International Journal of Science Education, 38*(6), 922-933.

Ramnarain, U., & Padayachee, K. (2015). A comparative analysis of South African Life Sciences and Biology textbooks for inclusion of the nature of science. *South African Journal of Education, 35*(1).

Ryan, A. G., & Aikenhead, G. S. (1992). Students' preconceptions about the epistemology of science. *Science Education, 76*(6), 559-580.

Sánchez, G., & Valcárcel, M. V. (1999). Science teachers' views and practices in planning for teaching. In: Wiley Online Library.
Solaz-Portoles, J. J. (2010). Nature of Science and Science Textbooks: A Review of Research. *Educacion Xx1, 13*(1), 65-80.

Upahi, J. E., Ramnarain, U., & Ishola, I. S. (2020). The Nature of Science as Represented in Chemistry Textbooks Used in Nigeria. *Research in Science Education, 50*(4), 1321-1339.

van Dijk, E. M. (2011). Portraying Real Science in Science Communication. *Science Education, 95*(6), 1086-1100.

Wang, H. A. (1998). *Science Textbook Studies Reanalysis: Teachers*. Paper presented at the National Association for Research in Science Teaching, San Diego.