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The Relationship between Understanding the Nature of Scientific Knowledge and Reasoning and Decision Making in Socioscientific Issues*

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ABSTRACT

This study aimed to investigate the existence of a possible relationship between reasoning and decision-making in socio-scientific issues (SSI) and understanding the nature of science and scientific knowledge (NOSSK). Since a significant part of the SSIs are related to the field of biology, 50 pre-service biology teachers who had NOSSK training and were likely to have different levels of NOSSK understanding were studied. Using Views of Nature of Science - Form C [VNOS-C] modified by Abd-El-Khalick in 1998, participants were divided into three groups: naive, eclectic, and conscious-informed, who differed in their understanding of NOSSK. The Survey on the Decision-Making Process about Socioscientific Issues (SDMPSI), developed by the authors, aiming to reveal the approaches of all three groups to the discussion of cholesterol, was applied. VNOS-C and SDMPSI questionnaires were analyzed with content analysis guided by the criteria related to NOSSK prepared based on the literature and sample answers based on both the targeted NOSSK understanding and traditional science understanding; qualitative data were supported with quantitative data by making statistical analyzes. The significant difference ($p<0.01$) between the individual performances in SDMPSI of the naive, eclectic and conscious-informed groups supports the relationship between understanding NOSSK and socioscientific reasoning. It has been shown that socioscientific reasoning is a complex process that can be influenced by non-scientific factors such as personal experiences, moral concerns, but an up-to-date and adequate NOSSK understanding can reduce the degree of influence of non-scientific factors on the reasoning process.

Keywords: Socioscientific issues, scientific literacy, the nature of scientific knowledge, reasoning, decision making

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1. INTRODUCTION

Socioscientific issues (SSI) arising from science and scientific practices contain the dilemmas that have two consequences, both of which are unacceptable for equivalent reasons and force people to choose one of these two most undesirable options (Acar, Turkmen, & Roychoudhury, 2010; Sadler, 2004; Sadler & Zeidler, 2005; Sonmez & Kilinc, 2012). These dilemmas make it difficult to reach a consensus and cause divisions among both the public members and scientists. Thus, people interpret the causes and consequences of the issue from different perspectives due to various factors such as moral, ethical, social, economic, cultural, political, scientific, etc. These conflicting interpretations of the issue come with both acceptable and unacceptable arguments; they are not completely right or wrong. For these reasons, SSIs do not have definite solutions (Sadler & Zeidler, 2005), are complex, open to interpretation, controversial (Sadler, 2004), and generally require moral and ethical reasoning and assessment of the advantages and disadvantages of opposing arguments (Acar et al., 2010). For example; the use of nuclear energy, human activities that cause global warming, consumption of GMOs as food, and the use of biological studies such as cloning, stem cell, and gene projects for unethical purposes, etc.

These contemporary world issues, whose causes and effects will increase rapidly as science and technology progress, have a complex structure that is not easily solvable. Therefore, all people, as citizens of the world, should participate in the process of making decisions about SSIs. Hence, according to the current literature on science education, students, regardless of which profession they will choose in the future, should be educated as science-literate individuals who have gained the necessary skills

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to make an informed judgment about SSIs and who can question the accuracy of information (Rahayu, 2019, Purwani, Sudargo, & Surakusumah, 2018; Vasconcelos, Cardoso, & Vasconcelos, 2018; Evren Yapicioglu, & Kaptan, 2017; Dauer & Forbes, 2016; Gutierez, 2015).

Scientific literacy refers to the ability to use evidence and data to evaluate the quality of information and arguments presented by scientists and mass media (Dragos & Mih, 2015, p.168). Individuals with this skill are expected to be able to criticize decisions about SSIs, produce new solutions when necessary, and justify the need to produce new solutions. On the other hand, being able to criticize SSIs, according to the literature on science education, is possible by understanding the evidence-based, social and cultural context-dependent, and changeable nature of scientific knowledge (Geopany, Hernawati, & Meylani, 2021; Herman, Owens, Oertli, Zangori, & Newton, 2019; Karisan, Yilmaz-Tuzun, & Zeidler, 2018; Lederman, Antink, & Bartos, 2014; Lederman, Lederman, & Antink, 2013; Yacoubian & Khishfe, 2018). In other words, according to the literature, there is a relationship between understanding the nature of science and scientific knowledge (NOSSK) and approaching socioscientific issues (SSI). For this reason, science-literate individuals are expected to firstly *understand how scientific knowledge is structured* and to perceive *the source and limits of scientific knowledge*, to question the reliability of the scientific knowledge on which the decision about an SSI is based, and to be able to describe the limits and power of this knowledge. For this, the individual should experience how scientific knowledge is structured in terms of both historical and sociological aspects, as well as psychological and philosophical processes, and should be provided with a multidisciplinary educational approach (Saribas, 2015; Turkmen, Pekmez, & Saglam, 2017). Based on this, education on the NOSSK has taken its place among the priority topics in the literature on science education. Especially in the last 40 years, studies have been carried out in many countries to determine how well students' understanding of the NOSSK is compatible with the contemporary understanding of science and to develop, implement, and evaluate curricula that will allow students to improve their perspectives and understandings (Erdas, Dogan & Irez, 2016). Likewise, in Turkey, studies on how NOSSK education can be integrated into primary and secondary education curricula have been carried out since the early 2000s.

On the other hand, teachers have an indisputable role in providing students with an adequate and contemporary understanding of the NOSSK and with scientific literacy. Studies show that teachers' awareness of socioscientific issues is reflected in their students (Nielsen, Evagorou, & Dillon, 2020; Cebesoy & Donmez-Sahin, 2013; Clakeburn, Downie, & Matthew, 2002; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006). For this reason, it is emphasized that teachers, with their understanding and approaches, are as important as, perhaps more important than, the curricula, in educating students as science-literate (Fakhriyah, Masfuah, Roysa, Rusilowati, & Rahayu, 2017; Irez, Han-Tosunoglu, Dogan, Cakmakci, Yalaki & Erdas-Kartal, 2018). From this point of view, for teachers to support their students' scientific literacy, they are first expected to be science-literate themselves (Fakhriyah et al., 2017). Therefore, teachers are primarily required to graduate with an adequate and well-equipped NOSSK understanding and with the ability to use this understanding when making judgments about SSIs (Irez et al., 2018).

Due to this expectation in the literature, the existence of this relationship has been investigated for decades to establish a scientific basis that can be a reference for major reforms in both teacher training and science education. While previous studies have shed light on the relationship between NOSSK understanding and socioscientific decision-making, the findings of these studies are often controversial because of the complexity and difficulty of the problem: while some studies pointed to an indirect or limited relationship, some studies failed to reveal such a relationship (Adal, 2019; Kutluca & Aydin, 2018). One of these studies was conducted by Bell and Lederman (2003). The authors used four different socioscientific scenarios on 21 university professors and research scientists, who hold significant public decision-making authority on science and technology-based issues in everyday life. In the study, two groups with very different understandings of NOSSK were formed, and no significant difference was found between these two groups in terms of reasoning and decision-making about socioscientific scenarios: both groups based their decisions on their values, moral/ethical values, and social concerns. Several other studies in the literature seeking answers to the same critical question have reported data that suggest that understandings of some aspects of the NOSSK may influence socioscientific reasoning, but that cannot adequately explain the relationship due to the complexity of the problem. For example, unlike Bell and Lederman (2003); Zeidler, Walker, Acett, & Simmons (2002), Walker & Zeidler (2003), Sadler, Chambers, & Zeidler (2004), and Khishfe (2012) used a single SSI with high school students. Each of the above studies used a different SSI and a different method. For example, Zeidler et al. (2002) determined that a judgment about animal rights, which is a moral and ethical issue, is only very limitedly influenced by the empirical and science-society interaction dimensions of the NOSSK but is mostly shaped by other factors. In addition, they determined that students tend to distinguish between the information they use to make personal decisions and the information produced in the scientific process, so students' views are not affected by scientific information. Several subsequent studies supported their findings. Walker and Zeidler (2003) using genetically modified foods and Sadler et al. (2004) using global warming revealed that only the views on the social dimension of the NOSSK affect the socioscientific reasoning process and the understanding of the other NOSSK dimensions did not have a significant effect. On the other hand, the study by Khishfe (2012) could not present findings showing the relationship in question sufficiently. In the study using the subject of genetically modified organisms, it was revealed that there was no significant difference between the decisions of the control and experimental groups and that the students' decisions were affected by moral/ethical, religious, economic, and health-related factors rather than the NOSSK. However, in the study, it was observed that compared to the pre-experiment process, 37% of the participants in the experimental group based their decisions on at least one of the aspects of the NOSSK (empirical, changeable, or subjective). Using the issue of exotic species Mikania micrantha, which causes economic and ecological problems, and conducted on university students, Liu, Lin, and Tsai (2011) reported findings suggesting that only views on the uncertainty and creativity dimensions of scientific knowledge affect socioscientific reasoning very limitedly, but they could not find any clue showing the effect of other NOSSK dimensions. Unlike the above-mentioned studies, there are also studies supporting this relationship. For example, one of these studies was done by Herman (2015). Aiming to explore how perceptions about global warming may influence the willingness to mitigate global-warming impacts, Herman (2015) studied 324 secondary marine science students trained in global warming, climate change, and the NOSSK. According to the findings of the study, the individual's commitment to take action to solve the relevant SSI and their solution proposals are affected to varying extents by both the understanding of the NOSSK and personal, social, and cultural needs. Another study examining the relationship in question was conducted by Kutluca and Aydin (2018) using nine different SSIs on 12 pre-service science teachers. The study, which supported the participants' basic knowledge of the NOSSK and socioscientific argumentation and their basic argumentation skills through presentations, classroom discussions, and small group discussions, concluded that NOSSK understandings significantly affected the quality of socioscientific argumentation. Similarly, Adal (2019), who conducted a study on 12 pre-service science teachers but used a single SSI (cultured meat), reported findings, some of which were consistent and some inconsistent with the findings of the literature summarized above. The study could not identify the effects of uncertainty and imagination and creativity dimensions of scientific knowledge on the decision-making process but found that observation-inference, subjectivity, and empirical and socio-cultural nature dimensions affect the decision-making process to varying degrees.

Most of the studies in the literature were conducted with high school students: the number of those conducted with pre-service teachers or working teachers is not sufficient. Nevertheless, the cognitive and social maturation levels of teachers who are responsible for the education of students, and the richness of their experiences (the education they received, the duration of their education, the experiences they gained, etc.) are different. Different mindsets created by these differences can significantly affect the quality of the reasoning process, the decisions to be taken, and the reasons for these decisions regarding the same SSI. Therefore, there is a need for more empirical research to be conducted with pre-service teachers or working teachers for reforms that will shape teacher training as well as science education. Besides, the contradictory and inadequate findings of the studies summarized above, despite their important contributions to the literature, are limited to the scenarios and questions used in the studies, their participants, and the characteristics of the researchers. Studies should use different SSIs, enroll different participants, and be conducted with different researchers to rule out the possibility that the findings are related to the content, the participants, and the characteristics of the researcher. Furthermore, the number of empirical studies to guide major reforms should be increased, and their content should be diversified.

1.1. Purpose of the Study

Taking the above-mentioned need as a starting point, this study aimed to examine whether there is a relationship between pre-service teachers' understanding of the NOSSK and their approach to SSIs and whether NOSSK education leads to a reasoning process that changes the way the individual approaches SSIs, that is, the role of NOSSK education in scientific literacy. Hence, although this study, by its nature and like all other studies, cannot reveal definite and generalizable results, it aims to present examples, explanations, and experiences that are expected to help us better recognize and understand the problem. These experiences to be revealed can provide scientific support that enables us to inquire about the importance, purpose, and effectiveness of contemporary approaches to science education and reorganize them. In this respect, the study is expected to make important contributions to both scientific literature and practice.

In summary, people unconsciously react by various methods to SSIs they encounter in their daily life. So, what is the place of NOSSK understanding among these methods? This study sought an answer to the question of *"Is there a relationship between an understanding of the NOSSK and approaching SSIs?"* Other than this main problem statement, the questions to be addressed in this study are:

1. How compatible is the NOSSK understanding of the prospective teachers who make up the study group with the contemporary understanding of science?
2. Is there a significant difference between prospective teachers' understandings of the NOSSK?
3. Is there a significant difference in terms of reasoning about SSIs and judgment qualities between the prospective teachers who have an understanding of science compatible with the contemporary literature and those who have a completely traditional understanding or who do not have views in line with the literature?

2. METHODOLOGY

2.1. Design of the Study

This study tries to find out whether there is NOSSK understanding behind the reasoning process and post-reasoning expressions and behaviors of individuals while making judgments about SSIs. In line with the existing literature, it was aimed to reveal whether an adequate understanding of the NOSSK and traditional understanding of science affect the socioscientific reasoning process and decisions differently. Moreover, it was aimed to systematically question the data obtained from the explanations of individuals, and to create a theory that explains the relationship between the NOSSK understanding and socioscientific reasoning and decision making. For this reason, this study used the *grounded-theory approach* from qualitative research designs, since the main emphasis of this approach is on the information obtained during the research and the approach allows to systematically reach a theory from the data (Bas & Akturan, 2008).

To achieve the objectives set in the study, first of all, the VNOS-C questionnaire was used to investigate participants' conceptions of the NOSSK. Based on the results of the questionnaire, the participants were divided into three groups in terms of their understanding of the NOSSK: naive, eclectic, and conscious-informed. Next, the Survey on the Decision-Making Process about Socioscientific Issues (SDMPSI) was administered to reveal individuals' approaches to the debates about cholesterol, which is an SSI. Later, it was examined whether naive, eclectic, and conscious-informed groups, who exhibited different levels of NOSSK understanding, differed in terms of the approaches, reasoning processes, and the quality and justification of their decisions. In this process, the statements written on the questionnaires were divided into meaningful parts, and these parts (data) were conceptualized to describe the pattern or phenomena within. The concepts developed were constantly compared during the data analysis to provide a well-supported explanation for the research question.

2.2. Study Group

It is the teachers who guide students in the process of developing their ability to reason about any SSI. For teachers to develop such a skill in students, they must first be able to make informed judgments while reasoning about SSIs. On the other hand, one of the disciplines from which SSIs arise is biology. Therefore, biology teachers, like all teachers, need to have knowledge of the nature of SSIs and the ability to reason about SSIs. Therefore, in this study, the target audience is pre-service biology teachers. It was aimed to carry out the study on a group that is familiar with the relevant SSI, can talk, generate ideas, and reason about the issue, and also have different levels of NOSSK understanding. The study used the criterion sampling method to select pre-service biology teachers who are thought to reveal rich data on the research problem and who are likely to have various understandings (conscious-informed, eclectic, and naive) about the NOSSK. As a result, the study enrolled a total of 50 prospective biology teachers studying at a public university in Istanbul, of whom 23 (20 females, three males; 46%) were fourth-year students and 27 (24 females, three males; 54%) were third-year students, with all having completed NOSSK education. In the study, participants' names were kept confidential for ethical reasons, and each of them was given a code from P1 to P50.

2.3. Data Collection Tools, Validity and Reliability

To achieve the objectives, the study administered two surveys: Views of Nature of Science – Form C (VNOS-C) and Survey on the Decision-Making Process about Socioscientific Issues (SDMPSI). The VNOS-C, which is used to reveal participants' conception of the NOSSK, was originally developed as a seven-item form by Lederman and O'Malley (1990), and it was later modified by Abd-El-Khalick in 1998 to become a form consisting of 10 open-ended items. VNOS-C aims to reveal conceptions about the nature of science (the empirical, creative, and theory-laden nature of scientific knowledge, social and cultural effects on scientific knowledge, observation, inference, and theoretical assumptions in science, the nature of scientific theories, the relationship and differences between scientific theories and laws, the social and cultural embeddedness of scientific knowledge, and the existence of a universal scientific method (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Although each question in the questionnaire aims to reveal the understanding about only one aspect of the NOSSK, this understanding can be revealed in other survey questions, as well (Irez, 2004). According to Irez (2004), this has two major advantages: it offers the participants the opportunity to reveal their understanding of the NOSSK in different questions with different contents, which, in turn, helps the researcher when analyzing the consistency of the answers given by the participants. Also, asking participants to support their ideas with examples provides another benefit in demonstrating their understanding of the NOSSK.

SDMPSI aims to reveal to what extent understandings of the NOSSK affect judgments about SSIs that may be encountered in daily life. This survey, developed by the researchers, contains a scenario *"Could Cholesterol We Know as Our Enemy Be Innocent?"* (see Annex-1a) and questions about this scenario (see Annex-1b). The text titled *"Could Cholesterol We Know as Our Enemy Be Innocent?"* deals with the emergence of the cholesterol theory and the debates and dilemmas that this theory caused among scientists. The scenario was developed using facts, factual data, and opposing arguments regarding the cholesterol debate. While developing the scenario, the views and arguments were brought together to directly or indirectly guide various debates about the dimensions of scientific knowledge, except for the "existence of the universal scientific method." The relevant scenario is related to an issue about which the participants were able to generate opinions and make judgments since it is frequently addressed by the media in Turkey, the country where this research was conducted. This scenario does not necessarily require the use of technical knowledge, nor does it prevent using special content knowledge. In addition, the issue is pedagogically appropriate for the students participating in the research.

The survey, after giving the scenario, includes eight questions, one of which contains two items, making a total of nine open-ended questions. Most of these questions are in the evaluation step of Bloom's taxonomy, which is the highest level of the cognitive field. The questions require participants to think critically, evaluate, and make judgments; therefore, they require a way of thinking that consists of high-order mental processes such as analysis, synthesis, and evaluation. For example, the first question of the survey (see Annex-1b) expects the participant to synthesize all of the thoughts and beliefs that they have adopted about the NOSSK and to reach a decision based on the criteria they have formed as a result of the synthesis.

When the first version of the survey including the draft scenario and 14 related questions was completed, it was submitted to four experts with expertise in the field of biology education for validity and reliability studies. The experts were asked to review the scenario and related questions in terms of structure, content, and scope, and to determine

- Whether the scenario can measure the relationship in question,
- Which dimensions about the NOSSK are included in the scenario,
- Through which sentences these dimensions are measured in the scenario,
- Whether the questions can measure the relationship in question,
- What dimensions of the NOSSK the relevant question measures.

Then, to investigate the agreement between the initial determinations and evaluations of the four experts who worked independently from each other, the inter-rater agreement was examined. The subjects on which the experts were in agreement or disagreement were determined, and the reliability formula proposed by Miles and Huberman (1994) to calculate inter-rater agreement

(Reliability=Agreement/(Agreement+Disagreement)

was used. As a result, the inter-rater reliability coefficient of SDMPSI was calculated as 0.74. Afterward, questions and sentences on which there was no consensus were edited until a consensus was reached. As a result of the discussions, some of the statements that were thought not to be able to reveal the aforementioned relationship were either removed from the scenario or edited based on the expert suggestions in a way not to contradict the real data or discussions. Further, five questions with an inter-rater reliability coefficient below 0.70 were removed from the survey, and two questions were gathered under one item. Finally, after making the necessary editions in terms of language and intelligibility, the SDMPSI was finalized.

2.4. Data Collection

First, the VNOS-C questionnaire was administered at the beginning of the spring semester of the 2013-2014 academic year. Before the administration of the questionnaire, the participants were informed about it and the purpose of the research. They were also notified that the questions in the questionnaire did not have right or wrong answers, rather they aimed to reveal their understandings of the NOSSK. Participants answered the questions in approximately 45 minutes, and no time or answer sheet limitations were imposed. One third-year and one fourth-year student refused to fill out the questionnaire.

One week after the VNOS-C questionnaire was administered, the SDMPSI was administered. The details regarding the VNOS-C questionnaire were reiterated. During the administration of the survey, where no time or answer sheet limitations were imposed, participants answered the questions in writing in 40 minutes, and no problems occurred.

2.5. Analysis of the Results of the VNOS-C Questionnaire

The results of the VNOS-C questionnaire were analyzed using the content analysis approach. In this process, first, by using sources such as Lederman et al. (2002), McComas (1998), and McComas, Clough, & Almazroa (1998), themes related to the dimensions of the NOSSK agreed upon in the literature and clues (codes) that enable reaching these themes were created, and they were used as criteria in the analysis (see Table 1).

Table 1.
Themes and Codes Used in the Analysis of VNOS-C

Related dimension of the NOSSK	The theme of the related dimension	Codes
Empirical nature of scientific knowledge	Scientific knowledge is based on evidence.	obtaining data, establishing a basis with experiments and observations, etc.
	It is not just based on direct observation.	indirect observation, inability to observe with sense organs, relying on abstract data, interpretation, etc.
	Evidence has a supporting role.	unprovable, inconclusive, impreciseness
Scientific Method	It is not single or universal.	Using different methods depending on paradigm, creativity, subject, and conditions
	It is not followed step by step.	Not consisting of sequential steps, etc.
Tentative nature of scientific knowledge	All scientific information is subject to change.	uncertainty, doubt, falsifying, the existence of natural events contradicting every scientific statement, being subjective, being questionable, etc.
	Change in sociocultural structure with new findings, interpretation of findings from different perspectives, change of dominant paradigm.	paradigm shift, the crisis of science, new findings with technology, research made according to social conditions, reinterpretation

The nature of Theory and Laws	Theories are well-supported explanations.	relying on data obtained by experiment and observation, explaining the causes of natural events, the best explanation, etc.
	Theories can change.	Falsifiable, not absolute, etc.
	Laws can change.	Falsifiable, not absolute, etc.
	There is no hierarchical relationship between theory and law.	Different types of knowledge, equally scientific, not interconvertible
Inference and theoretical entities in science	Some theories are formed as a result of scientific guesses, inferences, and assumptions.	making inferences and interpretations based on scientific evidence, etc.
The subjective and theory-laden nature of science	Observations are influenced by beliefs and values.	Scientists working with their own unique values and thoughts and making inferences accordingly, reflecting social and cultural values, being subjective.
	There may be differences in the interpretation of the findings.	looking at the same thing but seeing different things, etc.
Science and Society	Science is the product of culture.	Reflecting social and cultural values
	Society affects science.	The way of life and thinking of society, the system of beliefs and values affect every stage of scientific study
Creativity-imagination in science	Creativity and imagination are used,	developing different methods, interpreting from different perspectives, making different inferences, etc.
	At every stage	

In the written answers, firstly, the codes indicating the themes related to the dimensions of the NOSSK were searched. For this purpose, the answers given to each question were first broken down into meaningful parts (data), sometimes consisting of a single word, sometimes a sentence, or a paragraph. Similar data were brought together and coded to identify the pattern/event in them. The codes were brought together in a meaningful and logical way and gathered around a theme. Thus, participants' understanding of the relevant theme was revealed, and it was determined whether this understanding was compatible with the contemporary understanding of the NOSSK.

These analyses were first carried out by two researchers independently, and each researcher created a table showing the participants who expressed an opinion that was compatible or incompatible with 18 themes reflecting the contemporary understanding of the NOSSK. Then, the tables created by the two researchers were compared. The inter-rater agreement was found to be 0.94 with the reliability formula of Miles and Huberman (1994). This process continued until a consensus was reached on the codes.

Once a consensus was reached, the extent to which each participant expressed views compatible with the eight dimensions of the NOSSK and 18 related themes (individual performances) was calculated separately. In line with the purpose of the study, the participants were ranked according to their individual performances and divided into three groups: the naive group (those who expressed opinions compatible with five or fewer themes), the conscious-informed group (those who expressed opinions compatible with 14 or more themes), and the eclectic group (the others). While the conscious-informed and naive groups each consisted of nine participants, the eclectic group consisted of 32 participants. The definitions of naive, eclectic, and conscious-informed used when grouping are given in Table 2.

Table 2.
Definitions of Naive, Eclectic, and Conscious-Informed

Group	**Definition**
Naive	Those who have a completely traditional understanding of the relevant theme of scientific knowledge, that is, views that are not compatible with the contemporary understanding of science or literature
Eclectic	Those who adopt a fragmented approach to the relevant theme of scientific knowledge, which is formed by combining the contemporary and traditional understandings of science
Conscious-Informed	Those who have views on the relevant theme of scientific knowledge that are fully compatible with the contemporary understanding of science

Then, it was determined to what extent the conscious-informed, eclectic, and naive groups expressed views compatible with the contemporary understanding of science regarding each dimension of the NOSSK (group performance), and the compatibility percentage of each group's understanding of science with 18 themes (individual performance) was found. Later, statistical analyses were performed to reveal whether there was a significant difference between the group and individual performances of all three groups.

2.6. Analysis of the Results of SDMPSI

At this stage, the expressions and justifications used by each participant in their written answers were examined to determine how much they used their NOSSK understanding in the reasoning process. As exemplified in Table 3, in the answers, meaningful expressions (data) that suggest that the participant has a contemporary understanding of science and that there may be a relationship between reasoning about the SSI and understanding the NOSSK were primarily sought. Researchers interpreted these data based on the impressions that arose in their own minds and brought them together in a meaningful and logical way to form codes that describe the pattern in the data. Through these codings, participants' views about the SSI, which were expressed explicitly or implicitly in their written answers, were revealed. The view revealed during the coding process was matched with a theme belonging to the relevant dimension of the NOSSK. In this matching process, it was tried to reach participants' views about the themes and to reveal whether the underlying reason for their views was their understanding of the NOSSK. If the matching was possible, participants' views on each theme were combined to form a proposition, which was later accepted as the basis for their judgment about the SSI. However, if the matching was not possible, other factors underlying their judgments were explored. Thus, participants who based their reasons on contemporary or traditional understandings of science, who expressed misconceptions, or who were not able to express a clear view while reasoning and making decisions about the SSI were identified.

During this whole process, one of the guides of the researchers was the themes and codes prepared for the analysis of the VNOS-C questionnaire (Table 1). In addition, before the analysis of SDMPSI, sample answers based on both contemporary and traditional understandings of the nature of science for each question were created by taking into account the determinations and suggestions of the experts. In the analysis of the sample answers, to guide the researchers, meaningful expressions (data) were coded, as was done in the data analysis, the codes were matched with a theme belonging to the relevant dimension of the NOSSK, and the themes were combined to form propositions that could support the relationship in question. Below are two sample answers based on contemporary and traditional understandings of science for the fourth question in SDMPSI, and the coding procedures for the answer based on a contemporary understanding of science are shown in Table 3.

Sample answer based on a contemporary understanding of the NOSSK: "Cholesterol levels are the predictions made by scientists who interpret data obtained from experiments and observations. As we obtain new data that may conflict with the available data, create revolutionary crises, and change the perspective on the scientific question due to changes in the direction of research programs or developments in technology, or as we interpret the available data from different perspectives, predictions will also change. Therefore, it is normal for healthy cholesterol values to vary. However, it should be noted that the quality of scientific knowledge depends on the amount of money allocated to research and the number and quality of researchers, as well as data, imagination, and creativity. The suppressive control that the pharma industry that will finance the research may create on the researcher and the researcher's moral, cultural, and economic values also affect the process of determining the research topic and interpreting the data. As healthy cholesterol levels are lowered, the number of people who are considered to have high cholesterol values and are prescribed drugs will increase accordingly; thus, pharma companies and the doctors and scientists who collaborate with them can earn more money. In other words, cholesterol values may be arbitrarily lowered. No real scientist can or should be sure of the accuracy of any scientific information. A scientist should always be suspicious and live with the fact that their claim can be falsified.

Sample answer based on a traditional understanding of the NOSSK: "Since scientists are completely objective and analytical when solving a problem, the information they put forward precisely reflects the truth in nature. Science is, therefore, a collection of facts and is reliable. If scientific knowledge is constantly changing over time, that knowledge and scientist are not reliable. Such information and scientists are useless."

Table 3.
Sample Answer Based on a Contemporary Understanding of the NOSSK for the Fourth Question in SDMPSI

Data	**Coding**	**Related theme**	**Proposition explaining the relationship**	**Conclusion**
experiments and observations, data acquisition	Cholesterol levels are based on science	Scientific knowledge is based on evidence.	Scientific knowledge is imprecise predictions based on scientific data but is formed by reinterpreting these data under the influence of various factors such as culture, society, and economy.	The change in cholesterol levels over time has been answered based on an understanding of the nature of scientific knowledge.
interpretation, prediction	Cholesterol levels are a kind of supposition.	Theories are the result of inference.		
Conflicting data, interpretation from different perspectives	The basis for the cholesterol theory can change.	Scientific knowledge is tentative: it can change over time.		
effects on the interpretation process; moral, cultural, economic values and qualifications of the researcher	Different cholesterol levels can be suggested based on the same data.	There may be differences in interpretation. Observations are theory -laden.		
the pressure of pharma companies, moral, cultural, economic values and qualifications of the researcher, allocated allowance	Social, economic, and cultural factors have influenced the formation of the cholesterol theory.	Science is a product of culture. Society affects science.		
uncertainty, falsifiable		Scientific knowledge is tentative: it can change over time.		

All the analyses were carried out independently by the two researchers, and each researcher created a table showing the groups (conscious-informed, eclectic, and naive) depending on whether they used a contemporary understanding of the NOSSK when making judgments for each question of the SDMPSI. After comparing the tables created by the two researchers, the inter-rater agreement was calculated as 95.2% with the reliability formula of Miles and Huberman (1994). The researchers re-examined the data about which there was no consensus and the coding from these data until they reached a consensus on matching these codings with the relevant NOSSK theme.

After a consensus was reached, statistical analyses were performed to reveal whether there was a significant difference between the group performances and between participants' individual performances for each question of the SDMPSI.

2.7. Statistical Analysis

While evaluating the findings obtained from VNOS-C and SDMPSI, the Kruskal Wallis test was used for the comparison of the parameters that did not show normal distribution, and the Mann Whitney U test was used to determine the group that caused the difference. Also, the chi-square test was used to compare qualitative data. Statistical significance was set at $p<0.05$. Statistical analyses were performed using the IBM SPSS Statistics 22.0 software.

3. FINDINGS

3.1. Findings Related to VNOS-C Results

The groups' (conscious-informed, eclectic, and naive) understandings of science based on their written answers to the VNOS-C questionnaire are summarized in Table 4. In the first column of Table 4, there are the NOSSK dimensions researched in VNOS-C and the themes reflecting a contemporary understanding of science for these dimensions. Participants are shown in the upper line with codes such as P1, P2. Participants expressing opinions compatible with the relevant theme are marked with a "•". The boxes opposite the participants who expressed opinions that were not compatible with these themes were left blank. The "•"s across the themes were counted to determine to what extent each group and the whole sample expressed views compatible with a contemporary understanding of science (group performance), and this number is given in the far right column. The "•"s opposite the participant codes were counted to determine the compliance percentage (individual performances) with 18 themes reflecting a contemporary understanding of the NOSSK, and this number is given on the bottom line. The statistical comparison of the group performances for each dimension of the NOSSK and the individual performances of the groups are summarized in Table 5.

Table 4. *Summary of All Participants' Understandings of the Nature of Science and Scientific Knowledge*

	CONSCIOUS-INFORMED										ECLECTIC																																	NAIVE										
Dimensions of NOSSK and related themes	P4	P28	P29	P30	P32	P13	P31	P37	P3	**Total (%)**	P11	P1	P35	P26	P16	P7	P50	P25	P20	P34	P23	P40	P38	P5	P9	P6	P18	P47	P36	P22	P8	P33	P15	P46	P12	P2	P21	P27	P39	P44	P45	P19	**Total (%)**	P10	P48	P43	P24	P49	P41	P42	P14	P17	**Total (%)**	**Sample Total**
Empirical Nature of Scientific Knowledge																																																						
based on evidence		•	•	•	•	•	•	•	•	89	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•		•				•		•					•	•	•		62	•	•	•	•	•	•				67	%68
indirect observation is important	•		•	•	•	•	•			67	•	•	•	•	•	•	•	•	•		•	•			•	•	•		•				•		•		•		•		•	•	66			•		•					22	%58
supportive role of finding	•	•	•	•	•	•	•	•		89					•									•										•			•						12										0	%24
Scientific Method																																																						
not unique and universal	•	•	•	•	•	•	•	•	•	100	•	•	•	•	•	•	•	•		•						•		•		•		•										•	44	•									11	%48
not followed step by step	•	•	•	•	•	•	•	•	•	100	•	•	•	•	•	•	•	•								•		•		•		•										•	41	•									11	%46
Tentative Nature of Scientific Knowledge																																																					
all can change	•	•	•	•	•	•	•	•		89			•		•				•	•																							12										0	%24
with new findings	•						•	•	•	44		•		•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•			•			•			69							•			11	%54
Theory and Law																																																						
The theories are well supported.	•	•	•	•				•	•	67	•									•			•			•			•				•										19										0	%24
Theories can vary.	•	•	•	•	•	•	•	•	•	100	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•		•	•	•	•	•	•	•	•	•	•		•	•	•	91	•		•	•	•	•	•	•	•	89	%92
laws can change.	•	•	•	•		•	•			67			•		•				•	•																							12										0	%20
no hierarchical relationship	•	•	•	•	•	•	•	•	•	100		•		•						•				•		•		•		•						•							25								•		11	%36
Inference and Theoretical Entities in Science																																																						
Theories are the work of guesswork.	•	•	•		•	•	•		•	78	•	•	•	•	•	•	•	•	•		•	•	•		•	•	•		•		•		•						•		•	•	66										0	%56
Subjectivity and Theory-laden NOS																																																						
observations are biased.	•	•	•	•	•	•		•	•	89	•	•	•	•		•	•	•	•		•			•	•		•				•					•		•					47										0	%46
difference in interpretation	•	•	•	•	•	•	•	•	•	100	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•	•	•	•		•	•	•		•		•	•					75		•		•					•	33	%72
Science and Society																																																						
Science is the product of culture.	•	•	•	•	•	•	•		•	89	•	•	•	•	•	•	•	•			•	•	•	•			•	•		•	•				•	•		•	•	•			66		•								11	%60
affects social science.	•	•	•		•	•	•	•	•	89	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•	•		•	•	•	•	•	•	•	•		91		•								11	%78
Creativity and Imagination in Science																																																						
There is creativity in science.	•	•	•	•	•	•	•	•	•	100	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	100	•		•	•	•	•	•	•	•	89	%98
at every stage	•	•			•			•	•	56	•													•					•					•	•	•							19										0	%22
Total	17/18	16/18	16/18	15/18	15/18	15/18	15/18	14/18	14/18	**15/18 ; %84**	13/18	13/18	13/18	13/18	13/18	12/18	12/18	12/18	11/18	10/18	10/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	9/18	8/18	8/18	8/18	7/18	7/18	7/18	7/18	7/18	6/18	6/18	6/18	6/18	6/18	**9,2/18 ; %51**	5/18	4/18	4/18	4/18	4/18	3/18	3/18	3/18	3/18	**3,7/18 ; %20**	**9,3/18 ; %51**

Table 5.
Evaluation of Group and Individual Performances According to Groups in VNOS-C

	Conscious-Informed	Eclectic	Naive	p
	Mean±SD	Mean±SD	Mean±SD	
Empirical Nature of Scientific Knowledge	81.48±24.22	47.92±25.31	29.63±26.06	**0.001***
Scientific Method	100±0	42.19±49.37	11.11±33.33	**0.001***
Tentative Nature of Scientific Knowledge	66.67±25.0	40.63±29.61	5.56±16.67	**0.001***
Theory and Law	83.33±17.68	36.72±17.94	25±12.5	**0.001***
Inference and Theoretical Entities in Science	77.78±44.1	65.63±48.26	0±0	**0.001***
Subjectivity and Theory-laden NOS	94.44±16.67	60.94±39.62	16.67±25.0	**0.001***
Science and Society	88.89±22.05	78.13±33.45	11.11±33.33	**0.001***
Creativity and Imagination in Science	77.78±26.35	59.38±19.83	44.44±16.67	**0.001***
Individual Performances (%)	**100±0**	**42.19±49.37**	**11.11±33.33**	**0.008***

Kruskall Wallis test **p<0.01*

3.1.1. Group Performance

According to Table 4, the sample expressed conscious-informed opinions on NOSSK's dimensions of *empirical nature of scientific knowledge* (50%), *inference and theoretical entities in science* (56%), *subjective and theory-laden nature of science* (59%), *science and society* (69%), *creativity and imagination in science* (60%), while they expressed naive or eclectic views about the dimensions of the *scientific method* (47%), *the tentative nature of scientific knowledge* (39%), and *theory and law* (43%).

A statistically significant difference was found between the groups' understandings of the dimension of "empirical nature of scientific knowledge" (p<0.01, Table 5). The group performance of the conscious-informed group was significantly higher than that of the eclectic and naive groups (p<0.05), while no significant difference was found between the eclectic and naive groups (p>0.05). A reasonable proportion of all three groups (89%, 62%, and 67%, respectively) were aware that a scientist has to base on some evidence their explanation of the why/how of a natural event. However, the views of the sample on the role of evidence generally contradicted a contemporary understanding of science, leading to divisions among pre-service teachers (89% conscious-informed, 12% eclectic, 0% naive). P31's statements on the role of evidence reflect the prevailing understanding in the conscious-informed group. According to this understanding, since it will not be possible to obtain an infinite number of pieces of evidence and because of the problem posed by the inductive thinking process, no scientific knowledge can be proven: it can only be supported by evidence.

> *"It is impossible to completely prove a theory or hypothesis. The most possible conclusion can be reached through experiments carried out in conditions closest to the natural environment. No matter how many experiments are done to prove a scientific claim, definitive proof is not possible. We do 1,000 experiments. In the 1,001st experiment, we may arrive at a different conclusion. No scientific study has certainty. Therefore, every word spoken may have events that may contradict itself." (P31)*

On the other hand, the group performances of the conscious-informed and eclectic groups on the "importance of indirect observation" were the same (67% and 66%, respectively), which is quite interesting. While some eclectics believe that scientific knowledge is based *only* on evidence obtained through direct observations and accept that pieces of evidence support scientific claims rather than justify them, some argue that the evidence on which scientific knowledge is based cannot be obtained by direct means merely, and they accept that the evidence proves scientific claims. Two participants in the eclectic group (P16 and P21) stated, just like conscious-informed individuals, that scientific knowledge is based on evidence obtained both directly and indirectly, and that the evidence supports scientific claims instead of proving them.

> *"We may not be able to observe with our five senses and reach the right conclusion. However, indirect experiments are necessary for the accuracy of scientific knowledge. For example, we cannot see the parts of an atom, but we can determine its size and different parts through the rays being sent. (...)We cannot prove a scientific claim even if there are millions of pieces of evidence. If one experiment gives us a different result, it destroys millions of pieces of evidence (...). (P16).*

The conscious-informed group, with an understanding that the evidence cannot prove a scientific claim but can only support it, is expected to accept that the explanations brought to a scientific problem can never reflect the truth 100%, which is consistent with this understanding, and to be able to explain the reasons for this. Consistent with this expectation, the conscious-informed group's understanding of *the tentative nature of scientific knowledge* was significantly more compatible (67%) with the contemporary understanding of science than the eclectic and naive groups' understandings (41% and 6%, respectively)

($p<0.05$). On the other hand, there was no significant difference between the understandings of the eclectic and naive groups ($p>0.05$). While eight of the nine people (89%) in the conscious-informed group stated that scientific knowledge could change over time, surprisingly, only four (44%) of them expressed the fact that new data can reveal the inaccuracy of scientific knowledge due to factors such as differences in experience, imagination, and creativity, economic reasons, and technological developments. More interestingly, the eclectic group (69%) outperformed the conscious-informed group (naive group 11%). On the other hand, when all the results of the VNOS-C questionnaire are analyzed, it is seen that the conscious-informed group mainly attributes the reason for the change of scientific knowledge to *a paradigm shift* rather than to *"a change through new data obtained"* (P28, P29).

> *"They can change. With Thomas Kuhn's paradigm shifts, normal science goes into crisis, the expansion of theory in the era of extraordinary science brings science out of the crisis. So, theories can, of course, change."* (P28)

> *"Theories are supported by hypotheses, but no theory has ever been falsified just because it was not supported. Just as a paradigm shift, theories that cannot survive are replaced by another theory, the scene changes. (...)Scientific theories can change over time because it is the people who advocate the theory that make it valid. If one day this theory becomes unsupportable, then it undergoes a paradigm shift, and people thinking otherwise take the stage."* (P29)

In addition, compared to other groups, almost all of the participants in the conscious-informed group, when justifying the tentative nature of scientific knowledge, showed the effects of education, experiences, ideology, religious beliefs, personality, imagination, creativity, and socio-cultural characteristics of the society on scientists' process of interpreting and giving meaning to the evidence. Considering the group performances regarding subjective and theory-laden nature of science, 89% of the conscious-informed group argued that there was no objective observation in science, while 100% stated that there might be a difference in interpretation (P29). In the eclectic and naive groups, on the other hand, less than 50% held the belief that there was no objective observation (47% eclectic, 0% naive). While eclectics have a fragmented (partly compatible, partly incompatible with the contemporary literature) approach, they argue that observations are not affected by beliefs and values, and 75% of them stated that there may be a difference in interpretation. The naive group, on the other hand, mostly believes that science is completely objective and rejects the argument that scientists observe nature and make their explanations under the influence of their emotions, beliefs, and value judgments (P41). In other words, there was a statistically significant difference between the means of all three groups ($p<0.01$). The conscious-informed group's understanding of the objectivity in science is significantly different from that of the eclectic group, and the eclectic group's understanding is significantly different from that of the naive group ($p<0.05$).

> *"Scientists are affected by the environment, education, culture, religion, etc. Therefore, the concept of perspective arises. Reactions to the same event differ, truths differ. Because, as individuals, we are very different from each other, we are equal but different. (...) Scientists approach the same event from different angles. I think this is how it should be*." (P29)

> *"When I think of the word science, the first thing that comes to mind is objectivity. (...) This is what separates science from other disciplines. Because disciplines outside of science are knowledge that can be questioned continuously and also that form subjective value judgments." (P41)*

In addition, it was seen that the conscious-informed group's understanding of the science-society dimension was consistent with their above-described approach to objectivity in science. 89% (8/9) of this group saw science as a product of the society's way of living and thinking and consistently argued that social, economic, and political changes would direct the scientific study process and that science would be affected by social changes (P32). Considering the mean of the two themes belonging to the science and society dimension, the group performances of the conscious-informed and eclectic groups were significantly higher than that of the naive group ($p<0.05$), and there was no statistically significant difference between the means of the conscious-informed and eclectic groups ($p>0.05$). On the other hand, the eclectic group could not demonstrate the consistent approach that the conscious-informed group could. 66% of the eclectic group saw science as a product of culture, whereas 91% believed that science could be influenced by the society/culture that produces it; on the other hand, they also stated that the product of science was universal (P45). This inconsistent approach supports the view that the eclectic group has a fragmented approach to the NOSSK. 89% of the naive group, on the other hand, reflected the understanding that science is universal in all aspects.

> *"Science is definitely affected by social and cultural values. Because scientific knowledge is discovered or shaped by scientists. And scientists are naturally affected by social and cultural values. Indeed, Dalton discovered that he was colorblind as a result of these. If he had not belonged to a sect where colorful clothing was not welcomed and had not been stared at for wearing a red shirt, perhaps he would not have realized that he was colorblind or would not have discovered this disease."(P32)*

> *"Science is affected by society. Scientists can direct their scientific studies according to the deficiencies or leading thoughts of their society, but their science becomes universal after it is proven and improved." (P45)*

One of the notable findings belongs to the dimension of "theory and law in science." There was a statistically significant difference between the means of all three groups ($p<0.01$). The performance of the conscious-informed group was significantly higher than that of the eclectic and naive groups ($p<0.05$). On the other hand, the majority of the participants in this group (8/9; 89%) stated *openly* that scientific knowledge could change, and in line with this, all participants in the group accepted that theories could change. However, only 67% of the group held the belief that laws were, like theories, changeable information. Despite showing a higher performance than the eclectic (4/32; 12%) and naive groups (0/9; 0%), a significant part (33%) of the conscious-informed group had misconceptions about laws and demonstrated a fragmented approach like eclectics, which is a noteworthy finding (P13 and P37). Considering the whole sample, the number of participants expressing opinions compatible with the theme *"all scientific information can change"* is only 12. However, two of the 12 people say that no scientific knowledge can be proven, while, at the same time and inconsistently, they believe that laws are immutable knowledge. Only 12 participants stated that theories are propositions that explain the causes of natural phenomena, supported by data obtained through experiments and observations, and only 18 participants thought that there could not be a hierarchical order between a theory and a law because they express different types of knowledge (P3). While the majority of the participants (64%) considered laws to be more reliable and important than theories, few of them considered theories more important for the advancement of science as they create new questions and new fields of study, they allow explanations, and they can be improved.

> *"Theories may change. Because they were produced only based on the conditions of nature and the views of the scientists at that time. These theories may change if more logical ideas develop after them. (...)It is a fact that both can change. Theories are more subjective, while laws are facts that can be proven, that is, that offer more satisfactory proof. For example, it is very difficult to prove the theory of evolution, and it is open to discussion; opinions may vary from country to country, but the law of gravity is provable and universally accepted. There is no distinction between them in terms of status; the only difference is whether they are universal or not."* (P13)

> *"The law is final, it exists; you see or you know it. A theory, on the other hand, is an explanation of a law or a situation. As a classic example, I can give the law of gravity: it is a fact. But on the other hand, the theory of evolution (...) it is not a fact. Laws are of course superior to theories, at least for the public. But this is not so for scientists, nor should it be. When we ask people, they will consider the heart to be more important than blood, but without our blood circulation, our heart alone is useless. The opposite of this is also true. That's why I don't think there is a high level of status difference between theories and laws." (P37)*

> *"I believe that theories and laws have the same scientific significance. Because theories do not always become laws. Both are scientifically existing constructs and are of almost equal significance."* (P3)

While scientists try to find a solution to a problem, they try to interpret the evidence they have obtained, try to make sense of it, and make inferences. When doing so, they may have to assume several processes or relationships that they cannot observe directly or indirectly. Hence, in the literature, conscious-informed people are expected to accept the existence of predictions and theoretical assumptions in science. According to Table 4, the conscious-informed group held this belief more than the other groups (78%, 66%, and 0%, respectively), and no statistically significant difference was found between the means of the conscious-informed and eclectic groups ($p>0.05$, Table 5). In the eclectic group, too, some held this belief (P35), while none of the participants in the naive group were able to express the fact that there could be predictions and theoretical assumptions in science: they could not state a view on this dimension in line with the contemporary literature, or they made statements that suggest that scientific knowledge is the result of discoveries.

> *"Frankly, the atomic theory is still controversial. Since it is not possible to see atoms, scientists have made assumptions as a result of their experiments. I think scientists have made indirect inferences in order to determine the structure of the atom. Unfortunately, it is not possible to split the atom and examine its inside." (P35)*

Another factor that created conscious-informed, eclectic, and naive differentiation in the sample is related to the dimension of "creativity and imagination in science." There was a statistically significant difference between the means of all three groups ($p<0.01$). The views of the conscious-informed group were significantly more compatible with the contemporary understanding of science than those of the eclectic and naive groups ($p<0.05$), but there was no significant difference between the eclectic and naive groups ($p>0.05$). Regarding this dimension of NOSSK, only one participant (2%, P48) thought that there was no place for imagination and creativity in science because science should be objective. All the other participants (49/50; 98%) agreed that the process of explaining or modeling natural phenomena requires creativity and imagination. However, only 11 participants held the belief that imagination and creativity were used in all stages of scientific work, from defining the problem to determining the method, interpreting the data, and making inferences, which is in line with the contemporary understanding of science. Five of these 11 participants belong to the conscious-informed group (56%), while six belong to the eclectic group (19%). The statements of P4 and P12 reflect the beliefs of those who expressed opinions in line with the contemporary understanding of science. In the naive group, on the other hand, none of the participants thought that creativity and imagination were used at every stage of scientific work (P48).

> *"Yes, they use creativity and imagination. In fact, at all stages: starting the experiment, during the experiment, at the end of the experiment, even at the stage of deciding the problem... Two people reflecting on an event or two*

experiments can produce different results. After all, simple logic may not give us results sometimes. Or there is no such thing as visible, it can occur as a result of various assumptions." (P4)

"Yes, they use creativity and imagination. They use them at every stage. For example, when collecting data, where and how to collect data, or what experiments to do after collecting data are related to imagination and creativity. (...) If scientists create something in their heads, they can create or prove it in real life, as well. I think this has to be done in science." (P12)

"Creativity and imagination add subjectivity to the analysis stage. But I think objective thoughts should be valid on this issue."(P48)

One of the themes that shape the contemporary understanding of the NOSSK and cause division among the participants is related to the method applied while producing scientific knowledge. There was a significant difference between the compatibility of the three groups' views about the dimension of the scientific method with the contemporary understanding of science ($p<0.01$). The performance of the conscious-informed group was significantly higher than those of the eclectic and naive groups ($p<0.05$), whereas no significant difference was found between the eclectic and naive groups ($p>0.05$). All the participants in the conscious-informed group (100%, 9/9%) stated that science does not have a single and universal method to provide information about the physical world, arguing that the path followed may differ depending on the scientist, paradigm, creativity, the field of science studied, the subject, and other conditions. While only 41% (13/32) of the eclectic participants and only 11% (1/9) of the naive participants expressed an opinion that is fully compatible with the contemporary understanding of science, one eclectic participant believed that there was a single and universal scientific method, but this method was not followed step by step. Other eclectic and naive participants mentioned the existence of a single, universal method that is followed step by step, contrary to the fact that the ways of obtaining information about the physical world may differ. P35's statements reflect the beliefs of those who expressed an opinion compatible with a contemporary understanding of science.

"Actually, most people agree that there is such a method. It is said that scientists follow this scientific method step by step. But I think this is wrong. Since every person is different, the scientific methods used by scientists also differ. So, I think there is no universal method. (...) As I said, scientific methods and techniques used by scientists differ. Rather than a single universal method, there are as many scientific methods as there are scientists." (P35)

3.1.2. Individual Performances

Individual performances show the extent to which the participants have a consistent view with the 18 themes given in Table 4 that reflect a contemporary understanding of the NOSSK. Individual performances of the conscious-informed group ranged from 14/18 (78%) to 17/18 (94%), while that of the eclectic group ranged from 6/18 (33%) to 13/18 (72%), and that of the naive group from 3/18 (17%) to 5/18 (28%). There was a significant difference between the individual performances of the groups ($p<0.01$). The conscious-informed group's performance was significantly higher than that of the eclectics, and the eclectic group's performance was significantly higher than that of the naive group ($p<0.05$). This shows that the groups' understandings of science are compatible with a contemporary understanding of science to varying degrees and that SDMPSI, which examines the relationship between understanding the NOSSK and socioscientific reasoning, can be administered to this sample.

3.2. Findings Related to the SDMPSI Results

In this part of the study, the groups' answers to the SDMPSI were analyzed to determine the effects of their understanding of science on their reasoning about socioscientific issues. The obtained results are presented in Table 6. The first column of this table indicates the numbers of the questions in the SDMPSI and the NOSSK component directly or indirectly indicated by the questions, and the participants are shown in the upper row with codes such as P1, P2. Participants who made judgments based on a contemporary understanding of science while reasoning about the socioscientific issue given in SDMPSI are marked with a "•". The boxes opposite the participants who demonstrated a traditional understanding of science, who had misconceptions, or who could not express clear views were left blank. The "•"s were counted to determine to what extent the NOSSK understanding was reflected in the reasoning process *(individual performances)*, and the total number is given in the total line. The "•"s across the questions were counted to determine the *groups' performance*, and the total number is given in the total line. The statistical comparison of the individual performances of the participants and the group performances of all three groups for each SDMPSI question are summarized in Table 5.

First, the groups' performances for each SDMPSI question and the individual performances of the participants were evaluated to determine whether they reflected their understanding of science in the decision-making process. Afterward, group and individual performances were compared to reveal whether there was a relationship between understanding the NOSSK and socioscientific reasoning.

Table 6.
Reflection of All Participants' Understandings of Science on the Reasoning Process in Socioscientific Issues

Decision Making Survey (SDMPSI)	CONSCIOUS - INFORMED										ECLECTIC																																	NAIVE										
	P4	P28	P29	P30	P32	P13	P31	P37	P3	**Total**	P11	P1	P35	P26	P16	P7	P50	P25	P20	P34	P23	P40	P38	P5	P9	P6	P18	P47	P36	P22	P8	P33	P15	P46	P12	P2	P21	P27	P39	P44	P45	P19	**Total**	P10	P48	P43	P24	P49	P41	P42	P14	P17	**Total**	**Sample Total**
1. question																																																						
Overview of the NOSSK		•						•		2/9 %22																																	0/32 %0										0/9 %0	2/50 %4
2. question																																																						
Empirical NOS	•	•		•	•					4/9 %44	•	•				•			•		•													•									6/32 %19										0/9 %0	10/50 %20
3. question																																																						
Observation-Inference	•	•	•	•	•	•	•	•	•	9/9 %100	•	•	•	•		•		•		•	•	•	•	•	•	•		•		•			•		•			•					18/32 %56		•		•		•			•	4/9 %44	31/50 %62
4. question																																																						
Theoretical Assumptions	•	•	•		•	•	•	•		7/9 %78											•		•			•			•		•		•		•	•							8/32 %25		•			•				•	3/9 %33	18/50 %36
5. question																																																						
Theory- Law										0/9 %0																																	0/32 %0										0/9 %0	0/50 %0
6. question																																																						
Structure of Theory	•	•		•	•		•		•	6/9 %67			•	•		•	•	•		•		•	•			•	•	•	•	•		•	•		•				•				17/32 %53						•			•	2/9 %22	25/50 %50
7. question (A)																																																						
Paradigms	•	•	•	•	•	•	•		•	8/9 %89	•	•	•	•	•	•			•	•		•	•	•		•			•					•	•								15/32 %47						•			•	2/9 %22	25/50 %50
7. question (B)																																																						
Tnetative NOS	•	•	•	•	•	•			•	7/9 %78	•	•	•	•	•	•	•	•		•	•	•	•	•	•		•		•	•	•	•	•	•					•			•	23/32 %72		•	•				•	•		4/9 %44	34/50 %68
8. question																																																						
Science-Society	•	•		•			•	•	•	6/9 %67		•	•	•								•	•	•					•				•				•	•	•				11/32 %34		•								1/9 %11	18/50 %36
Total	7/9; %78	8/9; %89	4/9; %44	6/9; %67	6/9; %67	4/9; %44	5/9; %56	4/9; %44	5/9; %56	5.4/9 %61	4/9; %44	5/9; %56	5/9; %56	5/9; %56	2/9; %22	5/9; %56	2/9; %22	3/9; %33	2/9; %22	4/9; %44	4/9; %44	5/9; %56	6/9; %67	4/9; %44	2/9; %22	4/9; %44	2/9; %22	2/9; %22	5/9; %56	3/9; %33	2/9; %22	2/9; %22	5/9; %56	3/9; %33	4/9; %44	1/9; %11	1/9; %11	2/9; %22	3/9; %33	0/9; %0	0/9; %0	1/9; %11	3.1/9 %34	0/9; %0	4/9; %44	1/9; %11	1/9; %11	1/9; %11	3/9; %33	1/9; %11	1/9; %11	4/9; %44	1.9/9 %20	3.2/9 %36

Table 7.
Evaluation of group and individual performances according to groups in SDMPSI

	Conscious-Knowledgeable	Eclectic	Naive	p
	Mean±SD	Mean±SD	Mean±SD	
Bireysel performanslar (%)	60.56±16.05	33.59±18.75	19.56±16.29	[2]**0.001****
	n; %	**n; %**	**n; %**	
Overview of NOSSK	2; 22.2	0; 0	0; 0	[1]**0.009****
Empirical nature of science	4; 44.4	6; 18.8	0; 0	[1]**0.060**
Observation- inference	9; 100	18; 56.3	4; 44.4	[1]**0.028***
Theoretical assumptions	7; 77.8	8; 25	3; 33	[1]**0.014***
Theory-Law	0; 0	0; 0	0; 0	-
Theory structure	6; 66.7	17; 53.1	2; 22.2	[1]**0.142**
Paradigms	8; 88.9	15; 46.9	2; 22.2	[1]**0.015***
Tentative NOS	7; 77.8	23; 71.9	4; 44.4	[1]**0.233**
Science-Society	6; 66.7	11; 34.4	1; 11.1	[1]**0.047***

*[1] Chi-Square test [2]Kruskall Wallis test *p<0.05 **p<0.01*

3.2.1. Group Performance of the Sample

The first SDMPSI question (see Annex-1b) aimed to reveal the effects of participants' *general understandings*[2] of the NOSSK on their views about the emergence of the cholesterol theory, drug production based on this theory, and applications of theory, and their position for and judgments about the issue. However, none of the participants in the naive or eclectic groups resorted to the NOSSK understanding when reasoning and making decisions about or justifying their decisions about the issue. Only two conscious-informed participants' overall conceptions of the NOSSK (4% of the entire sample) influenced their decisions and judgments. This does not support the hypothetical relationship between understanding the NOSSK and socioscientific reasoning. The reasons why especially the conscious-informed group was unable to reflect their understanding of science in the first question (contrary to what was expected from them) are discussed in the next section, which examines the relationship in question. Nevertheless, despite the low performance of the conscious-informed group, there was still a statistically significant difference between the mean of this group and the means of the eclectic and naive groups (p<0.05). This situation and the fact that the reasons of P28 and P37 and the understanding they displayed in VNOS-C overlap, suggest a tendency towards the relationship in question. For example, P37, in the entire VNOS-C survey, implied that it is impossible to prove any scientific knowledge or to accurately reflect the truth since it is not possible to obtain an infinite number of pieces of evidence due to limitations. The participant also stated that although scientists try to be objective, they cannot get rid of their personal characteristics while doing their studies. The same participant based his/her judgment on following the doctor's recommendations in the first SDMPSI question on his/her views about the dimension of "subjectivity in science," which the participant also reflected in VNOS-C, but the participant also noted that he/she could not completely trust the list or program that doctors recommend, arguing that science does not consist of indisputable facts and that scientific knowledge can change.

> *"Science reflects social and cultural values. Because no matter how objective a scientist tries to be, he/she cannot leave his/her personality or moral values outside the laboratory. In other words, scientists live and work with their unique values and thoughts and draw conclusions and interpretations accordingly."* (P37, an excerpt from VNOS C)
>
> *"I test a theory or hypothesis with the requirements of the hypothesis that I put forward. As long as it is possible, I test the theory under every circumstance. I think you can never fully prove that. But ultimately because humans have limited possibilities and limitations, the theory may end up being considered proven or true. (...)"(P37, an excerpt from VNOS C)*
>
> *"I would trust my doctor and change my daily routine. Because I don't know why the researcher didn't use some of the data. But that doesn't mean the researcher lied. Looking and seeing are different things. We look at the same thing but see different things. Even if they are scientists, the data they accept may change. Even the education and personalities of scientists affect what data they accept or not or how they interpret the data in order to reach a conclusion. In addition, this theory was accepted by most scientists as a result of scientific debates. This allows a single scientist to distance himself a little from his personal prejudices and interests. Besides, scientific knowledge should be based on observations and experiments that have been verified multiple times. These cholesterol levels have been tested hundreds of times: I don't think tens of thousands of researchers are lying altogether. But this also depends on the list or program my doctor recommends. The reason why I don't fully trust my doctor's recommendations or don't*

[2] All the thoughts and beliefs about the nature of scientific knowledge as a whole, without regard to particulars, that are not specific to any aspect of the nature of scientific knowledge.

always follow them is because of the changeable nature of science, drugs, causes of illness. This prevents me from having full faith." (P37, an excerpt from SDMPSI)

Similarly, in VNOS-C, P28 argued that he/she attached importance to a methodology that is in accordance with the nature/values of science and that the evidence obtained through experiments and observations cannot prove a theory or hypothesis in any way. Consistent with these statements and in response to the first SDMPSI question, P28 attributed his/her decision not to use cholesterol-lowering statins to the argument that the theory in question was not based on an appropriate/correct methodology and to the changeable and dubious nature of scientific knowledge.

"....For knowledge to be considered scientific, it must be obtained in a way that is compatible with scientific values. Yet, I do not think that a hypothesis can be proved by evidence obtained through experimentation and observation. I don't think anything is completely definite…" (P28; an excerpt from VNOSC)

"....I would not use them. Because the cholesterol theory on which this treatment is based was developed with an unscientific method. The treatment that I can accept should have a scientific basis, should include all available data. To validate a piece of information, data that contradicts the purpose should not be ignored. Why didn't the scientist who developed the cholesterol theory use some data? First, I'd like to know the answer to this question. If the reason is what I have just said, this theory is unscientific. In fact, it is not even a theory, in my opinion. A theory must be able to explain the cause and the effect. On the other hand, a hypothetical relationship is defined in the theory. So, this is not a theory but a law. Therefore, the reason for the high cholesterol levels in my blood may be something else, not the foods I ate as the doctor claimed. I would investigate the reason for this and would like it to be investigated further. In addition, the fact that a piece of information has been shown to be statistically correct does not indicate that it is actually correct. Scientific knowledge presented today or in the past should be open to doubt, debate, and criticism, whatever its consequences may be." (P28, an excerpt from SDMPSI)

It was observed that the other participants' judgments about the issue were affected by non-scientific factors such as individual benefits (K31), mistrust of doctors as a result of experience (P29), trust in the majority opinion or knowledge of the field (P6).

"If the doctor tells me that my cholesterol level is high and prescribes some drugs, I would hesitate to use them. Because it has been claimed that these drugs can cause certain disorders such as mental retardation and muscle weakness. I would do some research about it. If I am sure of the existence of such a situation, I would try to keep my cholesterol levels normal by only paying attention to my animal food consumption." (P31)

"I would definitely not use these drugs. Indeed, false-positive results may occur from kits used for serological tests in laboratories or from those working in the laboratory. (...)Today, doctors do not prescribe too many antibiotics. But, once, they were like, 'Let's see if this antibiotic is going to work.' Since I know this, I would make my own assessment. For example, I know that LDL cholesterol is triggered by stress; when I was in high school, my LDL cholesterol levels were high, and the doctor asked questions about my diet. The doctor was wondering if I ate too much fast food, but it was not the case. I don't trust doctors or their results." (P29)

"....I would not use the drugs because I would think about the cholesterol's functions in the cell membrane, that it is the main ingredient of hormones and that it is a very important fat." (P6)

The second question of SDMPSI (see Annex-1b) aimed to reveal whether the understanding of the empirical nature of scientific knowledge affects reasoning about socioscientific issues. There was no significant difference between the performances of the conscious-informed, eclectic, and naive groups (44%, 19%, 0%, respectively) in this question ($p>0.05$, see Table 7). The discrepancy between these performances and the group performances (81%, 46.7%, 29.7%, respectively) in the dimension of "experimentation in science" in VNOS-C does not support the investigated relationship. On the other hand, when the responses to the second question are analyzed one by one, a significant number of participants reflected in SDMPSI the same views that they reflected in VNOS-C. The understanding of the empirical nature of scientific knowledge of all of the participants in the naive group and most of the participants in the eclectic group (81%) did not affect their reasoning, whereas that of a significant portion (44%) of the conscious-informed group shaped their reasoning. For example, P28 wrote in VNOS-C that knowledge based on a large number of data -knowledge that is testable and repeatable- can be accepted by all people. Consistent with this argument and in response to the second SDMPSI question, P28, in order to change his/her decision, requested findings/data obtained by scientific methods and expected the findings to be questioned by the scientific community. The answer given by P28 reflects the overall attitude of the conscious-informed group.

"…A theory cannot be accepted or disproved based on a single piece of data. However, a large amount of data or evidence obtained through experiments and observations can either prove or refute a piece of information. In addition, these data should be obtained in the same way by different scientists at different times. (...)" (P28, an excerpt from VNOS-C)

"For me to change my mind, I expect the subject to be questioned from different angles and to have sufficient scientific data in front of me: When using the drug, is the cholesterol theory really related to the determined findings? Couldn't it be air pollution, cigarette smoke, or even passive smoking that causes heart attacks? If an unproven theory is later combined with technology and appears before me as a drug, of course, I would not use the drug at that point. I would use the drug only after different variables have been investigated and it has been approved by the scientific community." (P28, an excerpt from SDMPSI)

Others based their answers on non-scientific factors such as the harm caused by the side effects of the drug (P13), the opinions of the people they trust (P37), the reactions of the users of the drug/the majority, or they were guided by misconceptions (P8).

"....I would definitely not want to use a drug that can have very important side effects such as muscle weakness or mental retardation. Maybe I can get rid of cholesterol, but I can't find any cure for these disorders." (P13)

"(...) people whom I trust can change my mind. For example, if my teachers whom I trust support this drug, this may change my mind."(P37)
".....Accepting a scientific law from an unproven theory may change my mind. In this way, I can trust the drug more." (P8)

In the third question (see Annex-1b), which aims to discuss the difference between observation and inference (subjectivity) and imagination and creativity in science, the performance of the conscious-informed group was significantly higher than those of the eclectic and naive groups ($p<0.05$), and no significant difference was found between the group means of the eclectic and naive groups ($p>0.05$). The concordance between the conscious-informed group's performances in the dimensions of observation-inference (94.5%) and creativity and imagination in science (78%) in VNOS-C and their performance in the third SDMPSI question (100%) supports the relationship explored in this study. For example, P13, who stated in VNOS-C that the personal characteristics of scientists such as age, culture, and beliefs affect their perspectives on the data and the way they interpret the data and who argued that paradigm shifts may cause the theories to lose their validity, gave a similar response to the third SDMPSI question. The answer given by P13 reflects the overall attitude of the group.

"These two scientists may have had different life experiences. Their age, culture, background, sociology, religious beliefs, etc. may be reflected in their views. Different characteristics and lifestyles are reflected in these people's perspectives. (...)"(P13, an excerpt from VNOS-C)

"(...) what validates a theory is the people who advocate it. One day, a theory may become outdated by a paradigm shift and be replaced by another theory." (P13, an excerpt from VNOS-C)

"Yes, it is normal. Because these people's schools, cultures, ages, perspectives on the world, and experiences may be different; all these differences will definitely be reflected in the way they work and the way they interpret the findings. For this reason, disagreements often arise between them while supporting their own ideas. These disagreements can help destroy wrong paradigms and move closer to the truth." (P13, an excerpt from SDMPSI)

It was seen that the reasoning process of some of the participants in the conscious-informed group was not shaped by their contemporary understanding of science alone, but their personal experiences were also effective. For example, P29's reference to Prof. Dr. Canan Karatay in his/her answer although this doctor is not mentioned in the scenario shows the effect of the information gained through personal "watching" experience on his/her views.

"It's perfectly normal, but people get confused about what's right. For example, Prof. Dr. Canan Karatay is a cardiologist. Although there is such a thing as the Karatay diet, the professor applies or recommends these diets to prevent heart attacks. She claims that animal fats do not cause heart attacks, but carbohydrates do. (...)" (P29)

Some of the participants in the eclectic (44%) and naive (56%) groups could not express a clear view, and most of them based their answers on factors not related to the NOSSK.

The fourth SDMPSI question (see Annex-1b) aims to reveal whether the understanding that scientific theories are, to some extent, based on assumptions, as well as observations and experiments, (and therefore, there may be a difference between natural events in the physical world and scientific explanations for these events) affects the judgment about the SSI. Although they did not use the words "assumption" and/or "prediction," 78% (7/9) of the conscious-informed group, 25% (8/32) of the eclectic group, and 33% of the naive group (3/9) stated that cholesterol levels, which are a scientific prediction/assumption, may change due to changes in science, technology, society, and culture. P38's response to this question exemplifies the responses of those with similar thoughts. P38, who stated in VNOS-C that the knowledge accepted as correct may change as the data obtained through experiments and observations change and as new data are obtained, made an evaluation in the SDMPSI based on the same argument. In this question, the conscious-informed group's performance was significantly higher than those of the eclectic and naive groups ($p<0.05$), and no significant difference was found between the performances of the eclectic and naive groups ($p>0.05$). Also, the conscious-informed group showed the same performance (78%) in "theoretical assumptions" in VNOS-C and SDMPSI. Both results support this relationship. On the other hand, it is noteworthy that the eclectic group showed lower performance in SDMPSI (25%) than they did in VNOS-C (66%) and that the naive group, which is considered to have a lower level of understanding, outperformed the eclectic group in the fourth SDMPSI question. The reasons for this result are discussed in the next section, which examines this relationship.

> "*Since the first day, science has been evolving. At any moment, situations may arise that have never been seen or observed and that do not conform to existing theories. This requires changing the theory, doing new experiments and observations. For example, the atomic theory has been changed many times since it was first introduced. Who knows, in the future, a scientist may come up with a new atomic theory*." (P38, an excerpt from VNOS-C)

> *"(...) they cannot be completely sure. Because the things they put before us as scientific knowledge have changed constantly. Maybe new research can show that the previously accepted values were wrong, causing these values to change." (P38, an excerpt from SDMPSI)*

The fact that many of the participants frequently referred to the economic interests of the pharmaceutical industry (P29) and the change in the society's living conditions (P20) showed that factors other than NOSSK understandings, such as *economic/social factors*, shaped their reasoning process.

> *"….In my opinion, there is the pharmaceutical industry, that is, there is a market. When they reduce the cholesterol levels, more people become cholesterol patients naturally, so the industry can sell this drug to more people, for years." (P29)*

> *"I think it depends on the change in eating habits over time. Nowadays, as we consume foods that can cause obesity and increase cholesterol levels, such as fast food, we can have high cholesterol more easily. This is how normal levels are reduced." (P20)*

In the fifth question (see Annex-1b), which aims to discuss the relationship and difference between a theory and a law, participants with a contemporary understanding of science were expected to give an answer centered on the fact that Mevlut Durmus' statement, *"This is just a theory"* is wrong. However, it was observed that none of the 50 participants could sense the misconception in Mevlut Durmus' words, on the contrary, they reflected their own misconceptions about theories and laws (for example, P40), and a few of them based their answers on their understanding of other dimensions such as the changeable nature of scientific knowledge (for example, P5). The reasons for and results of this finding obtained with the fifth question are discussed in the next section, which examines the relationship in question.

> *"It is an unproven theory. If it were a law, it would be definite and final, and people would still not need to argue over it." (P40)*

> *"What Mevlut Durmus says resembles the fact that popular doctors express different views on TV or the same person shares different findings over time in different articles. (...) There can never be a proven scientific law. Because the scientist may say, 'I claimed so in the past because my data claimed so, but under today's conditions, I think differently.' Science is constantly evolving. With the advancement of technology, the number of new findings is increasing." (P5)*

The sixth SDMPSI question (see, Annex-1b) aimed to examine how well participants with a contemporary understanding of science questioned the validity, reliability, limitations, and strength of the theory that led to the SSI. Considering the participants' responses, half of the participants (25/50; 50%) based their reasons, albeit partially, on the contemporary understanding of science about the structure of theories. Six of these participants belong to the conscious-informed group (67%), 17 belong to the eclectic group (53%), and 2 belong to the naive group (22%). That is, more participants in the conscious-knowledge group than those in the naive and eclectic group used their understanding of the structure of theories when reasoning about the SSI. In addition, the conscious-informed group's performance seems to be compatible with the VNOS-C theme of "theories are well-supported explanations," which is the basis for this question. This situation supports the intuitive relationship that is assumed to be true in the literature. On the other hand, although the conscious-informed group had a higher mean in this question, no significant difference was found between the performances of the groups ($p>0.05$). It is particularly noteworthy that eclectics reflected in SDMPSI the contemporary understanding of science, which they could not reflect in VNOS-C, almost as much as the conscious-informed participants, and they based their answers on this understanding. This situation, rather than demonstrating the absence of the relationship in question, reveals the necessity of supporting the questionnaires to be used to reveal participants' understanding of science. The responses of P26 and P35, who used in this SDMPSI question a contemporary understanding of science that they could not use in VNOS-C, set an example for the responses of those who thought similarly.

> *"Scientific theory is achieving a scientific truth in line with the data obtained as a result of various hypotheses, observations, and experiments. This fact is the best explanation developed through data and is subject to change. (...) The cholesterol theory is based on data, and there are studies that still try to falsify it. Therefore, it may be scientific, but it may not be 100% true. Because there is nothing that is completely true or completely wrong in science.*

Conclusions are made as a result of studies, experiments, and interpretations made in the light of the data. But later they all might change." (P26)

"…In order to prove a scientific claim and make it accepted by humanity, there is a need for solid evidence and experiments. (...) So, I don't think it reflects reality. If it were a valid theory, it would take all the findings into account. For example, we do not yet know why they used the data from only 6 out of the 22 countries. Maybe if they had used the data of 22 countries, they could have reached a completely different conclusion." (P35)

The other half of the participants (25/50) either reasoned based on misconceptions, based their answers on factors not related to science, or were unable to express their views clearly. For example, some participants, such as K13, reasoned with moral concerns, which indicates that moral values, just like the NOSSK understanding, are influential on socioscientific debates.

"The scientificity and authenticity of the theory put forward by Keys are debatable in my opinion. I don't think it reflects facts. Again, as I said, I can't be sure that he didn't include in his findings six of the countries he researched to report cholesterol as a disease and strengthen the pharmaceutical industry. (...)" (P13)

Items A and B of the seventh SDMPSI question (see Annex-1b) addressed two different dimensions of the tentative nature of scientific knowledge. Item B investigated the effect on socioscientific reasoning of a contemporary understanding of science that all scientific knowledge can change for many reasons, such as due to obtaining new data and reinterpreting existing data from a different perspective. On the other hand, item A investigated the effect on socioscientific reasoning of a contemporary understanding of science regarding the obstacles to change in science -especially paradigmatic change-. Considering the responses given to item B, it was seen that the majority of the participants (34/50; 68%) reflected their understanding of the changeable nature of scientific knowledge (P4, P38, and P40). In this item, the conscious-informed and the eclectic groups had significantly higher means than the naive group, and no significant difference was found between the conscious-informed and eclectic groups. This finding and the relationship between groups' means from SDMPSI and VNOS-C, support the relationship between understanding the NOSSK and socioscientific reasoning. On the other hand, the similarity between the conscious-informed and eclectic groups' performances in SDMPSI and the fact that their performances were higher in SDMPSI than in VNOS-C indicate, as the finding from question 6 revealed, that the results of a science opinion survey supported by SSIs can be more reliable.

"…After all, scientific information may not always be totally accurate. (...) it can be falsified or changed as new data is obtained. There are many different variables that affect information and people, such as perspective and technology." (P4)

"Science is a process. It is always renewed with new research. A previously ignored case can bring research to a different dimension. There are many different variables that affect people, such as perspective and technology. This may lead to the emergence of new theories." (P38)

"Why not? If a scientist can come up with an alternative theory and prove it, the cholesterol theory can be refuted. Because theories can change over time. (...) But this requires a lot of observation, experimentation, and research (time)." (P40)

On the other hand, in item A, the conscious-informed group had a significantly higher performance than the eclectic and naive groups ($p<0.05$), and no significant difference was found between the group performances of the eclectic and naive groups. This finding also lends significant support to the relationship investigated in this study. Half of the participants (conscious-informed 78%; eclectic 47%; naive 22%) attributed to scientific paradigms the fact that the cholesterol theory is still not falsified despite all scientific evidence, underlying that once a scientific theory becomes a paradigm, it can only be invalidated by another candidate theory. The responses of P34 and P40 exemplify this understanding.

"It takes time for scientific knowledge to be thrown away. Kuhn argues that every scientist has their own paradigm and it is very difficult for a scientist to abandon their own paradigm to adopt a new one. In order for the paradigm to be destroyed, situations that contradict the scientist's paradigm and create discomfort in the scientist are required. In this case, science falls into depression. Then, previous knowledge is questioned, new knowledge is obtained, but old knowledge does not disappear immediately. As people who lived in the old society disappear and the new generation gets used to the new information, the new gradually replaces the old. And now new knowledge prevails." (P34)

"There is a principle in evolution. The simplest is the principle of being right. After all, the reason why the cholesterol theory is still valid is that there is no alternative theory. Because if you cannot disprove a theory, you must replace it with a more valid one." (P40)

In items A and B of the seventh question, there were also some participants who gave responses based on misconceptions (P37) or on factors not related to a contemporary understanding of the NOSSK, or who were unable to express their views clearly.

> *"Because, as I've said in my other answers, it's a strong theory. Otherwise, it wouldn't be a theory. But since it is not a law, I mean since its reasons cannot be proven, the debates continue." (P37)*

In the 8th question, which aims to discuss the relationship between scientific knowledge and socio-cultural values (see Annex-1b), the conscious-informed group had a significantly higher performance than the eclectic and the naive groups ($p<0.05$), and no significant difference was found between the eclectic and the naive groups. That is, compared to eclectic and naive groups; the conscious-informed group based its understanding of the science-society relationship more on socioscientific reasoning. This supports the argument that only a sophisticated understanding of the NOSSK can influence socioscientific reasoning. The responses of P27, P4, and P3 reflect the overall attitude of other participants, who based their answers on a contemporary understanding of the NOSSK. However, the performances of the conscious-informed, eclectic, and naive groups (67%, 34%, and 11%, respectively) are below the compliance rate (89%, 78.5%, and 11%, respectively) calculated for the "science and society" dimension of VNOS-C, which served as the basis for this question. This finding does not support the intuitive relationship accepted in the literature between understanding the nature of scientific knowledge and socioscientific reasoning. The reasons for the fact that group performances in VNOS-C and SDMPSI did not overlap are discussed in the next section that examines this relationship.

> *"Society definitely has an effect. Both the environment where the experiment is done and the people in that environment. Also, apart from these, the scientist who introduces this theory cannot leave out of the door his/herself, personality, or social culture while experimenting. It is quite normal for scientists to be affected as they make decisions based on these factors."* (P27)

> *"Yes, could be. After all, man is not like a machine. Man has rights, wrongs, value judgments. They may be affected by other factors. It is quite normal. Scientists may have different tempers, temperaments, characters, points of view. They are influenced by the society where they have grown up." (P4)*

> *"In one of our classes, we had learned that scientists may approach and interpret things differently due to social, cultural, etc. factors. Similarly, cholesterol levels may also differ due to reasons such as the dietary habits of societies and environmental factors. In addition, economic (drug) factors may cause different interpretations." (P3)*

The majority of the participants (64%) could not refer to a contemporary understanding of science in their responses or rejected the influence of social factors (P11), or they were unable to express their views clearly.

> *"I don't think they affect! No. Scientists do not do research thinking about their society. They do research based on experiments and observations. Social factors affect, and should affect, the social sciences, not the natural sciences." (P11)*

3.2.2. Individual Performances

As can be inferred from Table 6, the individual performances of the conscious-informed group range between 44% (4/9) and 89% (8/9), and the mean score obtained from the questionnaire is 5.44 (60.56%). None of the participants in this group were able to reflect a contemporary understanding of science to *all* SDMPSI questions. Three participants in only four out of nine questions and two participants in only five out of nine questions used the NOSSK understanding and performed worse than the other participants in this group. The individual performances of the eclectic group range between 0% (0/9) and 67% (6/9), and the mean score is 3.06 (33.59%). Some participants in this group used the desired understanding of science in five or six out of nine questions and outperformed some participants in the conscious-informed group. On the other hand, the individual performances of the naive group range between 0% (0/9) and 44% (4/9), and the mean score is 1.88 (19.56%). Two participants in this group used the desired contemporary understanding of science in four out of nine questions and outperformed many participants in the eclectic group, and even outperformed some participants in the conscious-informed group. The fact that many participants from different groups with different levels of NOSSK understanding showed the same performance in SDMPSI indicates the effects of non-scientific factors on socioscientific reasoning. On the other hand, the individual performances of the conscious-informed, eclectics, and naive groups differed statistically significantly ($p<0.01$). The mean of the conscious-informed group was significantly higher than that of the eclectic group, which was significantly higher than that of the naive group ($p<0.05$). The significant difference between the individual performances and the group performances of the groups suggests that there may be a relationship between understanding the NOSSK and reasoning about the SSI and that this relationship can become more evident when the individual becomes more aware of the NOSSK.

3.3. Examining the Relationship Between Understanding the Nature of Scientific Knowledge and Reasoning and Making Decisions about Socioscientific Issues

Due to their inherent dilemmas, SSIs cause divisions among both scientists and public members. To be able to solve the issue, one must first perceive the dilemmas inherent in the issue and realize that they can cause polarization. It should also be accepted that due to moral, ethical, social, political, economic, cultural, etc. factors, opponents may perceive the issue in different ways and may attribute different meanings to its causes and effects. This requires a contemporary understanding of the difference between observation and inference, and of imagination and creativity. Without the understanding that people making the same observations about the same issue can reach different conclusions, it is impossible to realize the fact that the dilemmas inherent in an issue can lead to divisions and that opposing groups can all produce reasonable and acceptable arguments. Moreover, it is impossible to accept the fact that opponents may bring different interpretations to the issue. Nor can it be appreciated that there may be different hypotheses, laws, or theories trying to explain the same phenomenon. In this case, the individual will not be able to produce a solution that can be accepted by the majority. In short, the assumption that different interpretations can be made about an issue is a prerequisite for the solution of SSIs. The conscious-informed group, which has this prerequisite understanding significantly more than the eclectic and naive groups, resorted to this understanding when responding to the third SDMPSI question. They also regarded the scientific discussions as a necessary process for questioning the existing paradigm and searching for a new paradigm – that is, for the development of science (e.g., P4 and P30). On the other hand, eclectic and naive participants who did not have this prerequisite understanding at the desired level mostly resorted to the factors not related to the NOSSK. This shows that as one becomes more aware of observation-inference (subjectivity of scientific knowledge) and imagination and creativity, one can better reflect one's understanding of science to the socioscientific reasoning process. The significant difference between the group performances of all three groups in the dimensions of "subjective and theory-laden natüre of science" and "imagination and creativity" ($p<0.01$) and the significant difference between the group performances in the third SDMPSI question (p0.05) support this idea.

> *"Yes, it's normal. Because everyone has different views and cultural backgrounds. Scientific circles that support scientists also have an impact. That is, scientific knowledge is subjective, not objective. Therefore, it is normal for scientists to contradict each other, even if they are trained in the same field, even if they are experts in the same subject. Moreover, scientific debates can help the dominant paradigm to be destroyed to form new paradigms. These debates among scientists also show that science is in crisis. Competing ideas undergo natural selection and ideas that are highly persuasive win. Unless people with other ideas appear on the stage, that is, unless such debates take place, commitment to the same paradigm continues, and thus science makes no progress. Besides, scientists, like other people, may act with the motive of being recognized and famous. Disproving a widely accepted theory can help them achieve recognition. And the other party, to protect their reputation, may defend themselves passionately, sometimes despite overwhelming evidence. So, I think there are many different reasons for such debates. But, as I said at the beginning, I think it is very normal and this is how it should be." (P4)*

> *"Of course yes. Because two different people looking at a chair can depict it differently, even if the chair is the same. Indeed, the chair is as plain as the nose on the face. On the other hand, a surgical event is much more complicated. And those who make observations and experiments, even if they are experts in that field, can still be wrong." (P30)*

After recognizing the dilemmas inherent in the issue, one should be able to question, by using analysis, synthesis, and evaluation skills, the validity and reliability of the theoretical basis on which the opposing claims are based, and to determine the limits and strength of this basis. This requires a contemporary understanding of the "structure of theories" and "theoretical entities." One should be aware that there must be enough quality data obtained from direct and indirect observations to explain what lies behind the relevant phenomenon. In addition, it should be admitted that scientists attribute meanings to the data and make inferences from them under the influence of different factors, such as educational background, ideologies, personalities. Without the understanding that theories are limited by the available data, by the imagination, creativity, and reasoning skills of the scientist, and by other factors that influence the scientist, it is not possible to accept the fact that the relevant theory reflects only a certain point of view on the issue and that there may be different points of view. In this case, one cannot begin to question the data that forms the basis of opposing claims, nor can one decide on the validity and reliability of the data. While the group performances calculated for the theme "theories are well-supported explanations" in VNOS-C were 67%, 19%, and 0%, respectively, those calculated for the sixth SDMPSI question were 67%, 53%, and 22%, respectively. The conscious-informed group, which seems to have the potential to question the validity of opposing theories and make evidence-based evaluations, has reflected this understanding in socioscientific reasoning. The fact that eclectics reflected in SDMPSI the understanding of science that they could not show in VNOS-C indicates that surveys researching views about the NOSSK should be supported by SSIs. On the other hand, the conscious-informed group, expectedly, performed in the fourth SDMPSI question on theoretical assumptions the same as they did in VNOS-C (78%), whereas the eclectic group's performance in SDMPSI (25%) was below their performance in VNOS-C (66%). Moreover, the fact that the naive group, which is accepted to have a lower level of understanding of science, performed in the fourth SDMPSI question better (33%) than the eclectic group does not support the hypothetical intuitive relationship mentioned in the literature. However, this finding, rather than pointing to the absence of the said relationship, may have different reasons that should be well considered. This finding shows that socioscientific reasoning is a complex process influenced by non-scientific factors such as personal experiences, moral concerns, economic/social and emotional factors, and prejudices and that the effect of these factors may increase as the level of knowledge-consciousness decreases. Eclectics, who take a fragmented approach by combining propositions made with current and traditional understandings of science, do not have an effective and holistic view of the NOSSK on which they can base their justification. For this reason, non-scientific factors may have been more influential on their reasoning processes. In addition, the limited ability of eclectics to use words may have placed a limit on their expressions or justifications. Indeed, some participants may have (in their minds) evaluated the SSI based on NOSSK understanding, however, their limited vocabulary or expression skills may have prevented them from clearly expressing their views.

On the other hand, to refute the opposing argument in a socioscientific debate, one must be able to recognize the misconceptions of the other party and falsify the opposing argument based on the contemporary understanding of science. However, none of the participants in the sample (including the conscious-informed group that was 83.5% compatible with the contemporary understanding of science in the "theory-law" dimension of VNOS-C) were able to realize the misconception in Mevlut Durmus' words, which was the subject of the fifth SDMPSI question. In fact, this is not surprising for eclectic (36.75%) and naive (25%) groups, which were, as a result of VNOS-C analysis, found to have misconceptions about theories and laws. The misconceptions of these two groups about the types of scientific knowledge directed their reasoning about the SSI arising from the applications of these knowledge types and affected their decision-making process and solution proposals. However, the conscious-informed group's performance in this question does not meet the expectations expressed in the literature, indicating the inadequacy of the contemporary understanding of the NOSSK alone in a socioscientific debate and the need to develop high-order mental skills such as analyzing and critical thinking.

To be able to question the validity and reliability of one's own argument and opposing arguments about socioscientific issues, one must first accept the fact that no argument can be totally right or totally wrong. This requires the understanding that scientific knowledge is open to change. Otherwise, the traditional understanding that scientific knowledge is absolute may lead to the belief that there is only one correct solution to the issue and cause all other solutions to be rejected without question. As such, a multidimensional solution – acceptable to all – cannot be developed for the issue. In addition, an individual who has this traditional understanding will not be able to produce a counter-argument that he/she will need to argue and make accepted the correctness of his/her own argument - in which he/she does not believe and which may threaten his/her own argument - and will not be able to reveal the falsity of this argument on the basis of evidence. On the other hand, the understanding that scientific knowledge can change depends, to some extent, on questioning and understanding the concept of "paradigmatic transformation," on examining the exemplary situations in the history of science, or on one's experiencing this transformation him/herself. Besides, one of the factors shaping the understanding of science

- is the knowledge/belief of how the individuals or institutions that ordered and/or financed the research can affect the process and the validity and reliability of the information to be produced.

For these reasons, if the intuitive relationship in question is real, one must attribute the reason for the fact that the cholesterol theory mentioned in the scenario is, despite strong debates and claims, still valid today, to the contemporary understanding of the paradigmatic transformation or to economic factors. In addition to the responses of P34 and P40, which are given as examples in the findings section, the responses of P36 and P31 also support this relationship. The significant difference ($p<0.01$) between the group performances in the ***"tentative nature of scientific knowledge"*** dimension in VNOS-C and the significant difference (p0.05) between the group means from the A and B items of the seventh SDMPSI question (which aims to discuss the change in science) show that as the level of awareness about NOSSK increases, the understanding of science is reflected more in socioscientific reasoning.

> *"I think the lack of a strong theory, the fact that the opposite claim has not been fully proven, is weak in destroying people's ideas. While it is very difficult to turn people away from what they believe, changing a society's mind requires strong data to replace that idea. Unfortunately, there are many factors in our country that may prevent this." (P36)*

> *"……The pharmaceutical industry, which is huge. Since the day that cholesterol was proven to be harmful, many pharmaceutical companies have produced cholesterol drugs. Telling people 'Yes, cholesterol is actually harmless, just watch what you eat' is something that pharmaceutical companies do not want at all. Institutions such as pharmaceutical companies can put pressure on scientists to get the results they want from the research they fund. Scientists, in turn, can manipulate data to meet pharmaceutical companies' expectations. Even if this situation negatively affects the scientificness of the information..." (P31)*

Similarly, the significant difference between group performances in the eighth SDMPSI question ($p<0.01$) shows that the conscious-informed group, compared to other groups, considers the influence of social factors on the formation of the cholesterol theory and opposing arguments to be normal and justifies this in accordance with a contemporary understanding of science. This is another important indicator of the existence of a relationship between reasoning/making decisions about SSIs and understanding the NOSSK. Indeed, in addition to the responses of P27, P4, and P3, which are given as examples in the findings section, the response of P37 who is in the conscious-informed group supports this:

> *"Yes, they may have had an effect. All kinds of changes that occur in the scientist's country and in the world leave traces in their work. In fact, Keys, before developing such a theory, may have been influenced by the frequent heart attack cases that became so big a problem during his lifetime that they were declared a national disaster. Also, pharmaceutical companies may have an effect on this. Perhaps pharmaceutical companies' funding of cholesterol studies may have reduced people's confidence in the cholesterol theory. Thus, opposing arguments emerged…"(P37).*

One of the remarkable findings is the following: when reasoning about the relevant SSI, the conscious-informed group used their understanding of the dimensions of scientific knowledge, observation-inference, theoretical entities in science, the structure of theories, paradigms, changes in science, and science-society relationship at a rate ranging from more than 50% to

100%. However, less than 50% used their understanding of the empirical nature of scientific knowledge or the general understanding of science. Nevertheless, the difference between group performances in the second question on the empirical nature of scientific knowledge is in favor of the conscious-informed group (44% conscious-informed, 19% eclectic, 0% naive). When responding to the first question that is based on a general understanding of science, only two people in the conscious-informed group resorted to the mentality they formed about the whole of science, and to all of the thoughts and beliefs they had adopted. On the other hand, other participants' reasoning was influenced by non-scientific factors such as individual benefits or emotions. This finding may be due to the fact that the understanding of ***the tentative nature of scientific knowledge*** (which includes all other aspects of scientific knowledge) has not developed at the desired level. This finding also supports the view that socioscientific reasoning is a complex process that is influenced by many factors as well as by NOSSK understandings.

4. DISCUSSION AND CONCLUSION

This study aimed to reveal the relationship between understanding the NOSSK and socioscientific reasoning and decision-making. As all previous studies conducted for the same purpose have revealed, this study, too, has demonstrated that socioscientific reasoning is a complex process that can be influenced by non-scientific factors, such as personal experiences, moral concerns, economic/social and emotional factors, and prejudices acquired through media debates. Besides, the significant difference obtained in this study ($p<0.01$, Tables-6 and 7) between the SDMPSI performances of the conscious-informed, eclectic, and naive groups (which complied with the contemporary understanding of the NOSSK at different levels) supports the relationship between understanding the NOSSK and socioscientific reasoning. All three groups had pre-service teachers making justifications under the influence of non-scientific factors. However, this significant difference between the scores of the three groups suggests that the more one is aware of the NOSSK, the less non-scientific factors influence the reasoning process, hence, the more conscious decisions one makes.

Although there was a difference in terms of the scores of the three groups, the mean scores were low in all three groups considering the total number of questions. One of the important reasons is the nature and difficulty level of the questions used in SDMPSI. To use the NOSSK understanding as a criterion in these assessment-level questions, first of all, the steps of knowledge, comprehension, analysis, and synthesis on NOSSK must be accomplished. This requires an educational environment that constantly exposes students to high-level questions and supports their critical thinking skills. Otherwise, even if one has knowledge about a subject, one will not be able to use this knowledge in the evaluation and decision-making processes. However, studies such as Koray, Altuncekic, & Yaman (2005), Bay (2011), Karaman (2018), Akkus, Kaplan, & Kacar (2010), Gurol Arslan, Demir, Eser, & Khorshid (2009), Bulut, Ertem, & Sevil (2009), Kantek, Ozturk, & Gezer (2010), Korkmaz (2009), and Kucukguclu & Kanbay (2011) have revealed that higher education in Turkey cannot provide a learning setting that boosts students' inquiring, critical thinking, and socioscientific reasoning skills. However, critical thinking, which is one of the most basic skills of scientific literacy, which is vital in the 21st century (Ekici, Abide, Canbolat, and Ozturk,2017; Yalcin, 2018), is a skill that activates conscious reasoning on socioscientific issues and enables it to be concluded successfully (Seferoglu and Akbiyik, 2006). This skill is a defense mechanism of the individual against a large number of pieces of information coming from the media, politicians, teachers, etc. with high or low potential to contribute to the solution of the relevant socioscientific issue and with different reliability-validity degrees, as well as against many people trying to convince the individual. Therefore, to train science-literate students who are competent to reason consciously about socioscientific issues, critical thinking needs to be encouraged in the schools of democratic societies. Otherwise, the nature of scientific knowledge may cease to be the basis of scientific literacy and turn into a dysfunctional pile of knowledge. On the other hand, since 2004, it has been demonstrated that high-order mental skills such as critical thinking, creative thinking, and asking questions should be supported in curricula at different levels of the Turkish education system (Reform Initiative in Education, 2005; Board of Education and Discipline, 2017; MoNE, 2016a). However, Turkey's increasing failure in PISA conducted by the OECD (Organization for Economic Cooperation and Development) (MoNE, 2016b) shows that more needs to be done than just including the targeted learning outcome in curricula. The most basic condition for providing students with critical thinking skills, which are required for socioscientific reasoning, is the training of competent teachers (Yildirim and Yalcin, 2008; Kilic and Erkus, 2015; Karaman, 2018; Aybek, 2016). For this reason, first of all, teacher training programs and teacher trainers should be able to evolve in a way that will improve the inquiring, critical thinking, and creative thinking skills and that will transform the value and belief systems of teachers, who are the most important components of the education system. This is because, as our research findings have revealed, the reflection of NOSSK understanding on socioscientific reasoning is affected by both one's cognitive structure (the meanings one attributes to the concepts related to the NOSSK and the connection one creates between these concepts) and the belief and value system that one creates through sources such as radio, television, and the Internet. For this reason, for the hypothetical intuitive relationship mentioned in the literature to emerge, both the cognitive structure and the belief and value system of the individual need to be transformed. One's thinking skills can develop only as one establishes relationships and interacts with his/her environment in a learning setting -not isolated from social life- that aims at developing his/her cognitive structure (conceptual change) and restructuring his/her beliefs and values. The more one thinks, the more he/she will perceive the multidimensionality that causes the complexity of the socioscientific issue, and the more he/she will begin to question the validity, reliability, limits, and strength of opposing theories. Indeed, recent studies such as Herman (2018), Herman, Zeidler, & Newton (2018), and Kinslow, Sadler, & Nguyen (2019) support this view. Just as everyone's conceptual change process and belief and value transformation take place in different ways, so scientific literacy is a different process for everyone, taking place in different ways. The nature of science education that does not trigger in the individual the process of conceptual change and transformation of beliefs and values is likely to fail to reveal the tendency that this research has shown exists.

Another important reason for the low level of individual performance in SDMPSI may be the participants' inadequate understanding of the "status of scientific knowledge" and "theory-law" dimensions, which include almost all the aspects of scientific knowledge. A contemporary understanding of these two dimensions requires an adequate understanding of the other dimensions of NOSSK (except for the scientific method) and being able to establish complex connections between the dimensions. However, the conscious-informed group's performance in the first and fifth questions of the SDMPSI (which were aimed at these two dimensions) shows that, even though they have achieved some degree of understanding of other dimensions, they were still unable to establish the desired connections or learn the concepts meaningfully, that is, they were unable to achieve a holistic understanding of the NOSSK that they could reflect on socioscientific reasoning. This finding supports the importance of the above-mentioned learning setting to ensure that the NOSSK understanding is reflected in socioscientific reasoning.

In addition, another reason for low individual performances may be insufficient vocabulary and expression skills. Some participants may, in their minds, have justified their socio-scientific reasoning based on their beliefs about the NOSSK, but may have failed to express their thoughts clearly. One can express the idea produced in his/her mind only to the extent that his/her language skills allow him/her (Altinors, 2010; Tanilli, 2000). In other words, language skills affect whether one can successfully express his/her ideas. Depending on the meanings attributed to the words and the expression skills, the thought expressed may differ from the idea produced in the mind (Altinors, 2010; Tanilli, 2000).

Although there was a difference between the scores of the three groups due to the above-mentioned reasons, the significant difference between the scores of the groups indicates that as the understanding of the NOSSK develops, it affects socioscientific reasoning more. This finding is consistent with the findings of other studies such as Zeidler et al. (2002), Sadler et al. (2004), Albe (2008), Liu et al.(2011), Herman (2015), Kutluca and Aydin (2018), and Adal (2019). However, all these studies, including ours, have shown that due to the complexity of the issues, views about only a few dimensions of the NOSSK, not a contemporary understanding of all dimensions of the NOSSK, are reflected in socioscientific reasoning. On the other hand, the socioscientific issue, methodology, sample, and data collection tools used in each of the studies to reveal participants' NOSSK understandings and to investigate the impact of their understandings on socioscientific reasoning differ in terms of quality and quantity. Therefore, NOSSK dimensions that have been shown to be effective in socioscientific reasoning vary from study to study. In our study, it was found that an understanding in accordance with the contemporary understanding of the dimensions of "observation-inference difference/imagination and creativity," "theoretical entities," "structure of theories," "paradigm shift/change in science," and "science-society" tends to affect socioscientific reasoning, whereas the effect of an understanding of the dimensions of "empirical nature of science" and "theory-law" on socioscientific reasoning could not be revealed. Zeidler et al. (2002) using a scenario about animal rights (which is a moral and ethical issue) with high school and university students, determined that, unlike the finding of our story, only the empirical and science-society interaction dimensions of the NOSSK had a very limited impact on students' socioscientific reasoning. Walker and Zeidler (2003) and Sadler et al. (2004) working on high school students also support Zeidler et al. (2002). Walker and Zeidler (2003) using the struggle against genetically modified foods and Sadler et al. (2004) using the global warming problem have shown that views on the social dimension of the NOSSK alone can affect socioscientific reasoning to varying degrees. Liu et al. (2011), who used the fight against the exotic species Mikania micrantha (which causes economic and ecological problems) on a sample of university students, found, unlike these studies, that only views on the dimensions of "uncertainty of scientific knowledge" and "creativity" had very limited influence on socioscientific reasoning. On the other hand, Khishfe (2012), using the issue of GMOs, showed that there was a significant difference neither between the decisions of the control and experimental groups nor between the pre-experiment and post-experiment decisions of the experimental group. However, the author also found that compared to the pre-experiment period, 37% of the experimental group based their judgments on the empirical, changeable, and subjective aspects of the NOSSK. This result suggests that there is a relationship between making decisions about the issue of GMOs and understanding these three dimensions of the NOSSK. Adal (2019), using the cultured meat issue with 12 pre-service science teachers, could not detect the effect of "uncertainty" and "imagination and creativity" dimensions of scientific knowledge on the decision-making process but observed that observation-inference, subjectivity, and empirical and socio-cultural nature of the NOSSK affected the decision-making process to varying degrees.

There are also studies such as Bell and Lederman (2003) and Walker and Zeidler (2007) reporting findings that contradict the main conclusion reached by our study and supported by the above studies. Unlike the studies above that support this relationship, Bell and Lederman (2003) used four different SSIs with 21 well-educated adults, university professors, and research scientists. The authors divided the participants into two groups considered to have very different understandings of the NOSSK, based on the results of the VNOS-B questionnaire and semi-structured interviews. Then, both groups were administered with a "Decision Making Questionnaire" consisting of scenarios and questions related to four different SSIs. Although the two groups had quite different understandings of the NOSSK, no significant difference was found between their decision-making processes on socioscientific scenarios: both groups reflected their personal values, moral/ethical values, and social concerns in their decisions. Walker and Zeidler (2007), using a socioscientific issue of GMFs, examined the implementation of an inquiry-based curricular unit designed to promote high school students' discourse and debate on the tentative, creative, subjective, and social aspects of science. The authors reported that aspects of the NOSSK did not enter the debate discussions.

In short, these few empirical studies, which can serve as a reference for major reforms, have produced contradictory findings that failed to explain the relationship in question sufficiently, due to the complexity of the problem. Nevertheless, overall, the findings of this study and other studies in the literature suggest a positive relationship between informed NOSSK views and quality socioscientific reasoning. Due to this relationship, understanding the NOSSK will continue to be one of the important objectives of science education and to guide educational reforms. Furthermore, the existence of this relationship shows that NOSSK education will be an investment in the world. Still, the capacity of this investment to achieve its purpose, that is, the capacity of the NOSSK understanding to shape the reasoning about socioscientific issues, primarily depends on the nature of science education.

Socioscientific reasoning is a complex process influenced by both NOSSK understandings and non-scientific factors. A significant portion of the study participants integrated their understanding of the nature of science into their socioscientific reasoning process, while a significant portion of them reflected certain non-scientific factors in their reasoning process. This suggests that one needs more than merely receiving education on the NOSSK to be able to reason effectively on socioscientific issues and that one can do so only to the extent that one can internalize the NOSSK. In other words, not only receiving the course on the NOSSK but also the quality of the course and the extent to which students have benefited from the course is important. Instead of simply giving and receiving information, it is important to learn to think and reason with the aspects of the NOSSK. Concepts to be learned about the NOSSK only become meaningful when they are related to the SSIs.

5. LIMITATIONS AND RECOMMENDATIONS

Curricula, instruction programs, or textbooks should not only provide information about the NOSSK: they should be reorganized to teach students to think and reason based on *the NOSSK aspects within* the framework *of SSIs and to change their value systems, beliefs, and perspectives* on SSIs. More importantly, teachers who implement these curricula or instruction programs or who use these textbooks in their classes need to be trained about how to use the NOSSK aspects in the socioscientific reasoning process. In-service training can only support this process. The main training on this subject should be delivered before pre-service teachers start teaching, that is, during their undergraduate education. Therefore, teacher training programs used in faculties of education should include not only NOSSK training but also training in the use of NOSSK aspects when reasoning about socioscientific issues. Yet, this training should not be in the form of just giving students some information and demanding this information from them in written tests: it should be given in a learning setting where SSIs and NOSSK are discussed freely and critically, where no restrictions are placed on critical thinking, and which ensures prospective teachers' active involvement in the learning process.

On the other hand, the data and findings of this study are limited to the questions of the VNOS-C questionnaire used to assess individuals' understanding of the NOSSK. Nevertheless, surveys on the nature of science available in the literature fail to sufficiently evaluate the aspects of today's science enterprise. For this reason, they are unable to accurately measure beliefs about the nature of scientific knowledge. Indeed, these scales do not seek answers to questions such as

- Despite all the moral, ethical, environmental, social, etc. problems that may arise, should a scientific study really be started or scientific knowledge put into practice?
- On what grounds should a scientific study be based?
- Should a scientific study have limits?
- How (according to what criteria and by whom, why) should these limits be determined?
- By whom and for what purpose can scientific studies be conducted?
- By whom, how, and for what purpose should a scientific study be funded?
- Should a scientific study or application of scientific knowledge be supervised, and if yes, by whom, why, and how?

To meet this gap in the literature, scales with a new paradigm should be developed. Furthermore, the fact that a significant number of participants reflected in SDMPSI the contemporary understanding of science that they could not reflect in VNOS-C, indicates that science opinion surveys should be supported by SSIs.

On the other hand, the results of this research are limited to the scenarios and questions used in the research. As discussed earlier, some of the answers to SDMPSI questions show that participants' familiarity or experience with the relevant socioscientific issue determines whether their NOSSK understandings affect the quality of the socioscientific reasoning process. Therefore, in order to eliminate the possibility that the findings are related to the content, different scenarios about different SSIs should be used in the research process. Besides, the results of this study are limited to the study group of 50 people, as well as the researcher's understanding of science, analytical skills, and worldview. Also, it should be noted that participants' vocabulary and expression skills affect the quality of the obtained data, and thus, the result obtained by analyzing the data. To eliminate the possibility that the findings are related to the personal characteristics of the participants and the researcher, larger samples of participants with different characteristics should be studied by a large number of researchers with different characteristics.

This research used only two scales, VNOS-C and SDMPSI, as data collection tools. Yet, triangulation of data collection methods can help to develop a more comprehensive understanding of phenomena, which, in turn, increases the validity of the research.

For example, holding semi-structured interviews after the administration of surveys may help to eliminate any misunderstandings and to better understand the reasons behind socioscientific judgment through an in-depth examination of participants' views (Bell & Lederman, 2003).

Research and Publication Ethics Statement

This study was written on the basis of the master's thesis titled "Understanding the Nature of Scientific Knowledge and Reasoning about Socioscientific Issues," which we completed on February 13, 2015. All processes of the study were carried out in accordance with the ethical rules of Hacettepe University Journal of Education.

Contribution Rates of Authors to the Article

The subject of the study was suggested by the second author, who is the thesis advisor. The text (scenario) and questions in SDMPSI were developed by the first author, and four experts, including the second author, examined their validity and reliability. The data analysis was first performed by both authors independently, and the codes were compared until a consensus was reached. Evaluation of the findings, discussion, conclusion, and development of suggestions were performed by the first author and supervised by the second author.

Statement of Interest

There is no conflict of interest to declare between the authors and other individuals/institutions/organizations.

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7. ANNEXES

Annex1. SURVEY ON THE DECISION-MAKING PROCESS ABOUT SOCIOSCIENTIFIC ISSUES (SDMPSI)

Annex1a: "COULD CHOLESTEROL WE KNOW AS OUR ENEMY BE INNOCENT?"(Scenario)

After the Second World War, when heart attack cases in the United States increased to such an extent that they were declared a "national disaster," a researcher named Ancel Keys developed a graph showing the relationship between fat consumption and deaths from cardiovascular diseases in various countries, based on the data he obtained after his clinical studies. Based on this ***graph***, Keys introduced a theory called the cholesterol theory. The theory posited that animal fats raise the cholesterol level in the blood, that high blood cholesterol caused cardiovascular diseases, and that the higher the cholesterol level, the higher the risk of heart disease and heart attack. According to Ancel Keys, this graph proved the relationship between cholesterol levels and heart disease, leaving no room for doubt. Keys studied 22 countries but ended up using the data from only six countries. He never provided any information on why he used the data from only six out of 22 countries. Despite causing controversy among scientists, this theory was generally accepted. Based on this theory, cholesterol levels considered healthy were determined. Healthy cholesterol levels, determined as 260mg/dl in the 1990s, were reduced to 200 mg/dl in the 2000s; today these levels are thought to be reduced to 180 mg/dl.

About 20 years after Ancel Keys first proposed the cholesterol theory, a different researcher from a different country, Dr. Akiro Endo found a molecule called "statin," which destroys the steroid metabolism of living things. Pharmaceutical companies, which brought together these two scientists (Keys and Endo), who had no knowledge of each other, funded some research. As a result of their research, it was stated that drugs containing the statin molecule reduced the level of cholesterol, which is also a steroid, thus preventing the risk of heart attack and atherosclerosis.

Today, based on many experimental and clinical studies, a group of scientists is questioning the cholesterol theory and the drug therapy based on this theory. These scientists argue that the drugs used to reduce cholesterol levels have many side effects, from muscle weakness to mental retardation. They also claim that if the data from all the 22 countries that Keys studied are analyzed, the link between fat and heart disease disappears completely. According to biologist Mevlut Durmus, "*As such, people believed and were made to believe that the thoughts that high cholesterol is harmful and that the drugs used to lower cholesterol are based on extremely scientific and indisputable facts and that this view is an indisputable fact and a scientific law. Yet, the link between cholesterol and various diseases is not a scientific law but just an unproven theory*."

According to the scientists who advocate the cholesterol theory, "even if the data from all countries are placed on the graph, there is a statistically significant relationship ($r=0.59$ ($p<0.02$)) between these two variables, and the fact that this relationship has been detected in hundreds of experiments is an important piece of evidence."

On the other hand, there are studies claiming an increase in cancer cases in people using cholesterol-lowering drugs, as well as academic publications claiming that these drugs prevent cancer. Despite all these debates that continue even today, the cholesterol theory continues to be accepted as a scientific fact by the majority.

ANNEX1b: SURVEY ON THE DECISION-MAKING PROCESS ABOUT SOCIOSCIENTIFIC ISSUES (QUESTIONS)

1. Consider that your cholesterol is slightly above normal values. Your doctor, after talking about the research on **statins and their proven** effects, wants you to use statins **to reduce** your cholesterol level and not eat cholesterol-containing foods, especially animal fats. After reading this scenario, what would you do in such a situation? Would you use statins? Would you change your diet? Or would you think this cholesterol level is not a problem? Can you give an answer with reasons? **(*GENERAL* UNDERSTANDING OF THE NATURE OF SCIENTIFIC KNOWLEDGE)**

2. What might change your decision in the first question about using statins? Can you give an answer with reasons? **(EMPIRICAL NATURE OF SCIENTIFIC KNOWLEDGE)**

3. Do you think it is normal for scientists who are experts in the same field to disagree with and contradict each other about the same issue? If yes, why? If not, why not? What could be the reason for this difference of opinion between the parties? Please explain with reasons.
   (OBSERVATION-INFERENCE DIFFERENCE (Subjectivity))
   (IMAGINATION and CREATIVITY)

4. Healthy cholesterol levels have been reduced several times. What do you think about this? How sure can scientists be, or should they be sure, that the values they last proposed as healthy are safe? Can you give an answer with reasons? **(Theoretical ASSUMPTIONS IN SCIENCE)**

5. How do you evaluate Mevlut Durmus' statements? Do you think the idea that high cholesterol is harmful is a proven scientific law? Or is it an unproven theory? Can you give an answer with reasons?
   (RELATIONSHIP AND DIFFERENCE BETWEEN THEORIES AND LAWS)

6. What do you think about the validity of the cholesterol theory? How scientific or true is the theory introduced by Ancel Keys? Can you give an answer with reasons? **(STRUCTURE OF THEORIES)**

7.
   A) What do you think about the fact that the cholesterol theory is still valid and has not been abandoned despite strong debates and claims and experiments and observations that falsified it? **(PARADIGMS)**
   B) Do you think the cholesterol theory may change in the future? Please explain with reasons. **(CHANGE IN SCIENCE)**

8. Do you think that social factors may have affected the cholesterol theory and opposing arguments?
   - If your answer is yes, what factors affected them and why and how did they affect them? Is this effect normal? Please explain with reasons.
   - If your answer is no, why do you think social factors did not affect them?
     (THE RELATIONSHIP OF SCIENTIFIC KNOWLEDGE WITH SOCIO-CULTURAL VALUES)