
Article History
Received: 15.01.2022
Received in revised form: 31.103.2022
Accepted: 02.05.2022
Article Type: Research Article

International Journal of Contemporary Educational Research (IJCER)

www.ijcer.net

# Determining Pre-Service Science Teachers' Perceptions Of Science, Nature Of Science And The Relationship Between Them

**Aslı Sade Memişoğlu[1], Betül Erçelik[2]**
[1]Dokuz Eylul University, 0000-0002-8412-6473
[2]Dokuz Eylul University, 0000-0003-1666-3602

**To cite this article:**

Sade Memişoğlu, A. & Erçelik, B. (2022). Determining pre-service science teachers' perceptions of science, nature of science and the relationship between them. *International Journal of Contemporary Educational Research, 9*(2), 378-394. https://doi.org/10.33200/ijcer.1058181

IJCER International Journal of Contemporary Educational Research
Volume 9, Number 2, June 2022, Page 378-394 ISSN: 2148-3868

# Determining pre-service science teachers' perceptions of science, nature of science and the relationship between them

**Aslı Sade Memişoğlu[1*], Betül Erçelik[1]**
[1] Dokuz Eylul University

## Abstract

Besides being a necessity for science education, understanding the nature of science and its concept also facilitates individuals' daily lives and affects their decisions as conscious citizens. This study aims to determine the pre-service science teachers' perceptions of science and their views on the nature of science and their relationship. The study was carried out with prospective science teachers from different undergraduate levels. Perception of Science Questionnaire and Views on Nature of Science Questionnaire were used as data collection tools. Pre-service science teachers' views on the nature of science were found to be inadequate. Nature of science views generally showed a positive tendency throughout the undergraduate education. The metaphors obtained from the concept of science were analyzed by content analysis. The metaphors obtained were categorized as dynamic, guiding, cumulative, requirement, and infinite. According to the results, the perceptions of pre-service science teachers were positive but also showed some deficiencies and misconceptions. Finally, 'although not statistically significant, pre-service science teachers' choice of metaphors differed according to their grade level. No statistically significant relationship was found between pre-service science teachers' views on the nature of science and their perceptions of science.

**Keywords:** Science education, Science, Nature of science, Metaphor

## Introduction

Scientific information has a structure that continuously changes with the works made and progresses by adding innovations. With the changes made in the Turkish science education programs in recent years, a transition to a system that makes students active, questioning, problem-solving, and producing alternative solutions, has been made. One of the goals of science education is to teach the features and methods of science (Doğan Bora, 2005). It is recommended that science teachers inform students about the characteristics of scientific information by taking into account the curriculum content (Unal Coban, 2010).

One of the key steps of raising students as individuals who understand science and the nature of scientific knowledge is to train educators in science and other fields as individuals embracing the nature of science and scientific knowledge (Yenice, Ceren Atmaca, 2017). That is why the opinion of teachers who interact with students individually is of utmost importance. Teachers' perceptions of science will shape students' students' thinking and influence the implementation of educational programs to the desired level. In order to properly convey the nature of science to students, teachers first need to understand this concept themselves (Bayır, 2016; Clough et al., 2020; Lederman, 1992. Messenger, 2020; January and Yeter, 2018). An individual's perception of science will also influence their actions. More importantly, scientific knowledge embraced by teachers also influences their teaching methods of the scientific processes (Bayır, 2016). The reason is, teachers' beliefs about the nature of science are associated with their teaching methods and the students' beliefs (Tsai, 2002).

The nature of science and science is intertwined since the former is a combination of multiple disciplines. The nature of science is a field that explores what science is, how it works, the epistemological and ontological foundations, what scientists do and how they interact with other scientists, how science influences society, and how society reacts to scientific findings.In other words, it is an interdisciplinary field that blends the interactions

* *Corresponding Author: Aslı Sade Memişoğlu, asli.memisoglu@deu.edu.tr*

between science and society (Mccomas, et al., 1998, p.4). The nature of science was expressed in seven sub-dimensions by Lederman (2007);

1. Observation and inference are different.
2. Theory and law are different.
3. Scientific knowledge includes imagination and creativity.
4. Scientific information is subjective and/or theory-loaded.
5. Science interacts with the social and cultural environment.
6. Scientific information is subject to change.
7. Scientific knowledge is experimental.

Although there is much research on the nature of science, students and teachers have difficulty understanding the notions of the nature of science (Williams and Rudge, 2019). Studies have shown that most students, prospective teachers, and teachers have inadequate knowledge of the nature of science and misconceptions (Aslan et al., 2009; Edmondson et al., 2020; Erdaş et al., 2016; Lederman, 1992). Teachers are less informed about the nature of science than the science content and usually make a distinction between these two concepts (McComas, 2017).

Several studies have shown that views on the nature of science could be improved using different teaching methods (Akerson et al., 2013; Cengiz and Kabapınar, 2017; Mesci, 2020; Tsybulsky, 2018; Williams and Rudge, 2019). However, the methods for teaching the nature of science are still investigated since participants were found to return to their previous views after a certain period (Mesci, 2020). Although the definitions and dimensions of the nature of science are expressed differently, educators agree on the importance of the nature of science, and researchers work on how to teach the nature of science more effectively (Emran et al., 2020).

Teachers express their ideas, concepts, and abstract things through metaphors without being aware (Arslan and Bayrakcı, 2006). What metaphors science teachers use in their statements, and how often or why they use them are not well understood (Pope and Gilbert, 1983). When using metaphors for science education, the selected instrument should be familiar to children, find its meaning in everyday life, the subject area knowledge has to be activated and developed before the instrument is used, and the link has to be clearly established (Cameron, 2002).

The ideas related to the concept of science can be explained with metaphors easily (Çavaş, et al., 2019). Metaphors are also a reliable way to clarify assumptions that cannot be expressed in any other way (Zheng and Song, 2010). Metaphors can be preferred as an auxiliary tool in order to examine the thoughts, beliefs and philosophies of pre-service teachers about teaching, learning and school (Saban, 2006). Metaphor studies can be divided into three categories: the interaction between students and institutions, teachers' perceptions of teaching and students' learning beliefs. Metaphor analysis is used in studies investigating perceptions of teachers (Rusznyak and Walton, 2014), students (Saban, 2009), science teaching (Seung et al., 2011), and professional identity (Thomas and Beauchamp, 2011) and school (Saban, 2008). This method is also used in determining the perceptions on more specific subjects like the greenhouse effect (Niebert and Gropengieße, 2014) and research (Pitchter, 2011). Since scientific attitude consists of too many factors, some difficulties are encountered in its measurement. Therefore, metaphors provide a useful toolto determining diffreent asoects of this concept (Desphpande, 2004; Saban 2009). Studies determining the perception of science through metaphors are limited. These include few studies with primary and secondary school students (Jakobson and Wickman, 2007; Bıyıklı et al., 2014) and studies including teacher candidates (Kösem, 2017; Çavaş et al., 2019; Özgün et al., 2018). Studies investigating the perception of science conducted with teacher candidates mostly state that teacher candidates have positive perceptions and have incomplete knowledge although not wrong.

Lakost stated that there is no right or wrong in science, and there is no universal method for scientific proof. Feyerabend, one of the greatest philosophers of the 20th century, stated that the social aspect of science lies at the heart of science, that lifestyles, information and experiences differ between people and this fact is reflected in science (Doğan et al., 2011). These properties expressed for science actually form the basis of the nature of science. In fact, the interaction of science with the social and cultural environment, as depicted in the sub-dimensions of the nature of science and addressed in our research, is a key feature of science. In order to learn scientific knowledge and improve attitudes towards science and scientists, attention should be paid to the nature of science (Clough et al., 2020).

The nature of science views of teachers, although studied in detail, still is not at the desired level. This study tries to delineate the nature of science views in more detail by using an additional tool of metaphor analysis. Since individual values are also reflected in science and science teaching, evaluating the opinions of prospective teachers' science perceptions and nature of science together will help better understand their scientific perspectives. There are no studies combining and interpreting pre-service science teachers' perceptions of science and views of the nature of science in the literature. Therefore, this study provides data richness and reduces uncertainty by using metaphor analysis to determine perception of science. Analyzing the relationship between science and the nature of science allowed the results to be evaluated from a different point of view and a broader perspective.

## Method

### Research Design

This study aims to determine prospective science teachers' views of the nature of science, their perceptions of science, and their relationship. An embedded mixed method design, which allows quantitative and qualitative research methods to complement each other, was used in this study (Creswell, 2011, p.544). Phenomenology and cross-sectional designs were used under qualitative and quantitative research models, respectively (Yıldırım and Şimşek, 2018, p. 69; Büyüköztürk et al., 2018, p. 186).

### Participants

Participants are prospective science teachers of a faculty of education from a state university in one of the cities located on the west of Turkey during the 2019-2020 academic year. Initially, 236 volunteers at different grades were given the Views on the Nature of Science Questionnaire (VNOS-C). In the second phase, the Perception of Science Questionnaire could be applied to 148 volunteers among the first group.

### Data Collection Process and Tools

In this study, the Views of Nature of Science Questionnaire (VNOS-C), developed by Us-El-Khalick and Lederman (2000) for science teacher candidates in primary and secondary education and adapted by Özcan (2013; 2018) to the Turkish language, was used to determine views of the nature of science. According to Aikenhead (1988), the uncertainty of these methods decreases as one goes from Likert-type to interviews. VNOS-C survey consists of 10 open-ended questions. The data analysis was performed with a Rubric Scoring System (RSS) developed, and validity/reliability was evaluated by Özcan (2013;2018).

A semi-structured form was used to determine metaphorical perceptions of the "science" concept. The first section of this form asked questions to identify demographic variables, such as grade and gender. The second section included a semi-structured sentence stating, "Science is ... like because ...". Before the application, the participants were given a description of what a metaphor is. They were given verbal instructions for using a single metaphor, making sure to produce a logical basis for choosing that metaphor and not making definitions while explaining it. The data was collected during a lesson hour.

### Data Analysis

#### *Views of Nature of Science Questionnaire-C (VNOS-C) Analysis*

The data was evaluated according to the Rubric Scoring System (RSS) developed by Özcan (2013: 2018), which categorizes the answers into "Not Acceptable – 0 points", and "Partially Acceptable – 1,5 points" and "Acceptable – 3 points". For the analysis of the data, SPSS 23 package program was used. To determine the distribution of the data, the total score of each participant was calculated, and the normality test of Kolmogorov-Smirnov was used.. Data showed normal distribution, therefore One-Way Anova analysis was performed.

The questions were also analysed according to the seven sub-dimensions mentioned in the study by Özcan (2013): tentative, empirically-based, observation and inference, theory and law, theory-laden, imagination and creativity, social and cultural context. Since groups were not normally distributed for all sub-dimensions, a non-parametric Kruskal-Wallis H test was performed.

***Perception of Science Questionnaire Analysis***

Metaphors developed by the participants were analyzed using content analysis techniques (Yıldırım and Şimşek, 2018) and the five phases applied by Saban (2008). These are (1) coding and extraction phase, (2) example metaphor image compilation phase, (3) category development phase, (4) validity and reliability phase, (5) data transmission phase to the SPSS 23 package program for quantitative data.

***Analysis of the Relationship Between Views of Nature of Science and Perception of Science***

The Chi-square independence test was used to determine whether there is a significant relationship between views of nature of science and perception of science (Fraenkel and Wallen, 2011, p. 234). For data obtained at VNOS-C, a participant's maximum score is 52.5. Based on this score, the total scores were grouped into three; those who scored 0-16 as unacceptable, those scoring 17-34 as partially acceptable and scores between 35-52.5 as acceptable. In order to determine the relationship of these groups with the metaphors, data from 89 participants were analyzed using a Chi-square independence test.

### Validity and Reliability

In order to o determine the reliability of the study, 25% of the data was analyzed by two separate researchers (O'Connor and Joffe, 2020) using the formula developed by Miles and Huberman (1994) (Reliability Percentage= Agreement / (Total Agreement + Disagreement)). Reliability was found to be 90% for the Views of Nature of Science Questionnaire. It is stated that "Reporting the collected data in detail and explaining how the researcher reached the results are among the important criteria of validity in a qualitative research" (Yıldırım and Şimşek, 2018, p. 270). The two researchers analyzed the metaphors obtained from the Perception of Science Questionnaire individually to determine whether they represent the categories, and the reliability was found to be 91%.

## Results and Discussion

### Pre-service science teachers' views of the nature of science

The mean values of the total scores obtained by the participants from the VNOS-C by class level are given in Table 1.

Table 1. Mean total scores of VNOS-C.

| | N | Mean | Std. Deviation | Std. Error |
|---|---|---|---|---|
| 1st grade | 60 | 16,1752 | 4,93848 | ,63756 |
| 2nd grade | 44 | 16,7727 | 5,22122 | ,78713 |
| 3rd grade | 69 | 15,8043 | 4,35571 | ,52437 |
| 4th grade | 56 | 17,7589 | 5,97570 | ,79854 |
| Total | 229 | 16,5655 | 5,12819 | ,33888 |

The maximum value participants can get according to the RSS is 52.5. Scores of 0-16 out of the total score are unacceptable, those with 17-34 are partially acceptable, and scores between 35-52.5 are acceptable. The majority of the respondents had an unacceptable (n=119) and partially acceptable (n=109) opinion. A respondent gives the highest score in the fourth grade, who is the only person with an acceptable view (36 points).

A graph of total score averages according to grade levels is provided in Figure 1. Pre-service science teachers' scores on VNOS-C tend to increase based on grade levels but generally, they have an unacceptable view. The decline in the scores of third-grade participants is thought to be affected by the difference in data collection time.

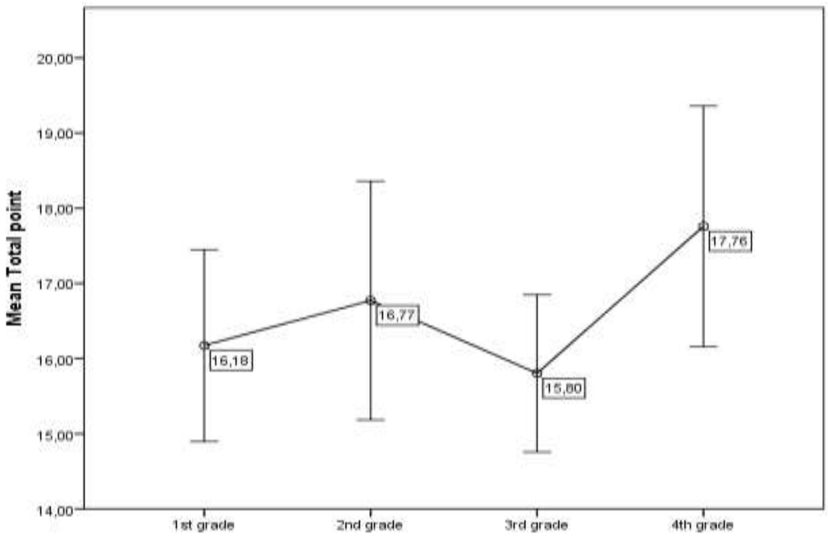



Figure 1. Graph of BDHGA overall class averages.

Table 2 shows the seven sub-dimensions of the nature of science to which the questions in the VNOS-C refer.

Table 2. Relationship Between the sub-dimensions and VNOS-C questions (Ozcan, 2013, p.119).

| Sub-dimensions of nature of science | Representative VNOS-C questions |
|---|---|
| 1. Scientific knowledge is tentative. (Tentativeness) | 1, 6, 7, 9, 10 |
| 2. Scientific knowledge is empirically based. (Empirically based) | 1, 2, 3, 6, 7, 9 |
| 3. Scientific knowledge is based on inference as well as observation. (Observation and inference) | 6, 7, 9 |
| 4. Theories and laws are different kinds of scientific knowledge. (Theory and Law) | 5 |
| 5. Scientific knowledge is theory-laden. (Theory-Laden) | 6, 9 |
| 6. Scientific knowledge involves imagination and creativity. (Imagination and Creativity) | 1, 4, 6, 7, 8, 9 |
| 7. Scientific knowledge is embedded in social and cultural contexts. (Social and Cultural context) | 1, 9, 10 |

The impact of grade levels of prospective teachers on sub-dimensions of the nature of science has been analyzed by the Kruskal-Wallis test (see Table 3). As seen in Table 3, the observation and inference dimension of the nature of science in prospective teachers varied considerably by class level, whereas class levels did not significantly differ for other dimensions.

Table 3. Relationship of grade levels with sub-dimensions of nature of science; Kruskal-Wallis test results.

| Null Hypothesis | p | Result |
|---|---|---|
| The distribution of Tentativeness is the same across grades. | ,243 | Retain $H_0$ |
| The distribution of Empirically-based is the same across grades. | ,278 | Retain $H_0$ |
| The distribution of observation and inference is the same across grades. | ,010 | Reject $H_0$ |
| The distribution of Theory and Law is the same across grades. | ,121 | Retain $H_0$ |
| The distribution of Theory-laden is the same across grades. | ,051 | Retain $H_0$ |
| The distribution of Imagination and Creativity is the same across grades. | ,243 | Retain $H_0$ |
| The distribution of Social and Cultural Contexts is the same across grades. | ,438 | Retain $H_0$ |

The rank averages of the pre-service science teachers for the observation and inference dimension of the nature of science according to their grade levels are 113.32 in the 1st grades, 118.08 in the 2nd grades, 97.05 in the 3rd grades, and 136.49 in the 4th grades. While the opinions of teacher candidates in terms of evidence and observation scale showed a tendency to increase based on class levels, there was a drop in third-grade participants, and they had the lowest rank average in this dimension. A post-hoc test was performed for this dimension since a statistically significant difference was observed in the Kruskal-Wallis test (see Table 4). Based on the Kruskal-Wallis post-hoc analysis results, evidence and observation showed a statistically significant difference between grades 3 and 4.

Table 4. VNOS-C evidence and observation dimension Kruskal-Wallis post-hoc result

| Grade | Test statistic | Standard error | Standart test statistic | p | Adjusted significance |
|---|---|---|---|---|---|
| 3-1 | 16,274 | 11,571 | 1,406 | ,160 | ,958 |
| 3-2 | 21,029 | 12,647 | 1,663 | ,096 | ,578 |
| 3-4 | -39,440 | 11,790 | -3,345 | ,001 | ,005 |
| 1-2 | -4,755 | 13,011 | -,365 | ,715 | 1,000 |
| 1-4 | -23,166 | 12,180 | -1,902 | ,057 | ,343 |
| 2-4 | -18,412 | 13,206 | -1,394 | ,163 | ,980 |

Comparative graphs of the acceptability levels of the responses given by the prospective teachers to the nature of science sub-dimensions are given in figure 2. Of the answers given by the pre-service science teachers for the tentativeness dimension of the nature of science, 50% are unacceptable, 20% are partially acceptable, and 29% are acceptable. The highest rate of acceptable answers was seen at the 4th-grade level. The majority gave unacceptable responses at all grade levels.

59% of pre-service science teachers have an unacceptable view about the empirically-based dimension of the nature of science. Pre-service science teachers mostly have an unacceptable view of the evidence and observation sub-dimension at all grade levels. 88.6% of pre-service science teachers' views on theory and law were unacceptable, 6.1% partially acceptable and 5.2% acceptable. However, in the first year teacher candidates, no one expressed an acceptable opinion about theory and law. Pre-service science teachers' thoughts about the theory and law dimension had the highest unacceptable rate compared to other dimensions of the nature of science. 37% of the answers given by the science teacher candidates for the dimension of theory-laden were unacceptable, 25% partially acceptable, and 39% acceptable. While 3rd-grade teacher candidates mostly gave unacceptable answers, they mostly gave acceptable answers at other grade levels. 45% of pre-service science teachers gave unacceptable answers in terms of imagination and creativity. They also gave mostly unacceptable answers at all grade levels. In terms of social and cultural impact, 41% of the answers given by pre-service science teachers, were acceptable, 22% were partially acceptable, and 38% were unacceptable. While 42% of the first-grade teacher candidates gave unacceptable answers, the other graders gave more acceptable answers.

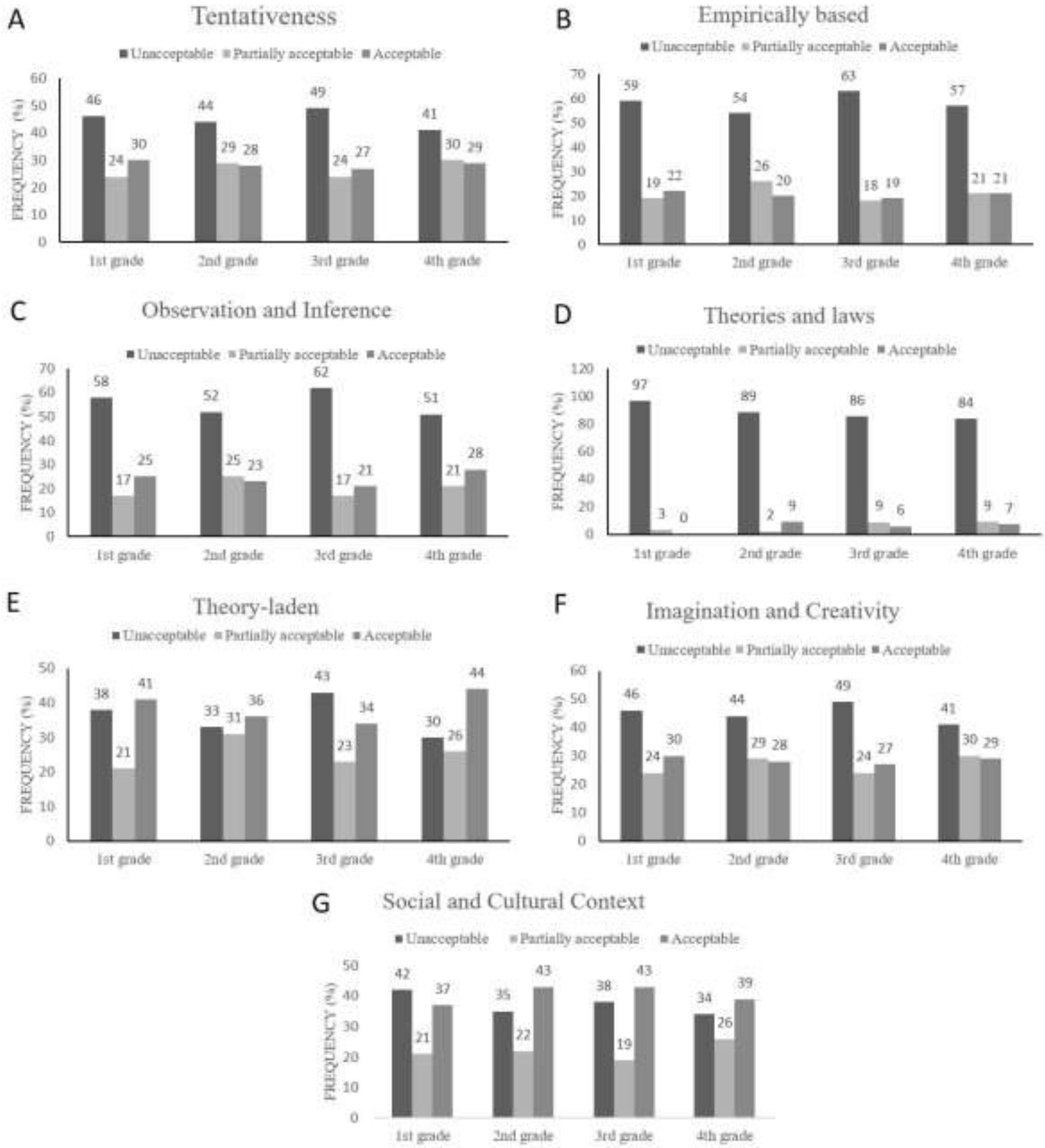



Figure 2. Comparative graphs of the acceptability levels of nature of science sub-dimensions.

## Metaphors on the Concept of 'Science'

Perception of Science questionnaire was applied to 148 prospective science teachers who also answered the VNOS-C questionnaire. After eliminating the invalid ones, data from 89 participants were analyzed. Responses with a science metaphor but no justification, or with a definition of science or left blank responses were eliminated (n = 59). The metaphors were analyzed using the "content analysis" techniques determined by Yıldırım and Şimşek (2018) and five steps set by Saban (2008), as stated in the methods section. Seventy-three different metaphors were obtained for 89 participants categorized, and provided in Table 5.

Table 5. Science Metaphors and categories developed by the prospective teachers for the concept of "Science"

| Category | Metaphor | Nb. Of Metaphors | f | Percent (%) |
|---|---|---|---|---|
| Dynamic | smartphone, masterpiece, baby, desert, sea, earthquake, nature, mimicking of nature in technology, to be born, spinning entity, earth, evolution, life, pencil and eraser, library, matryoshka, to wonder, seasons, fashion, river, ocean, bus, water, technology, years, road | 26 | 28 | 31.46 |
| Guiding | kidney, great events, living in touch with nature, the door to the world, education, the universe, the union of philosophy and humanity, the sun, the rays of the sun, the building block of our life, light, enlightenment with light, human, book, torch, magic wand, technology, technological tools, rain | 19 | 20 | 22.47 |
| Cumulative | water a tree, plant, magic, road with flowers, child, experiment, climb a wall, earth, sapling, planet to be discovered, book, penny bank, machine, matryoshka, fruit juice, history, pile | 17 | 17 | 19.10 |
| Requirement | family, mother, the complement of nature, sun, the essence of life, basis of life, our organ, water, basic need, puzzle pieces | 10 | 13 | 14.60 |
| Infinite | tree, child's questioning of the universe, sea, nature, cycle, universe, exploring the universe, cave, ocean, life itself | 10 | 11 | 12.35 |
| Total | | | 89 | 99,98 |

The percentages and and the number of metaphors in each category are given in figüre 3.

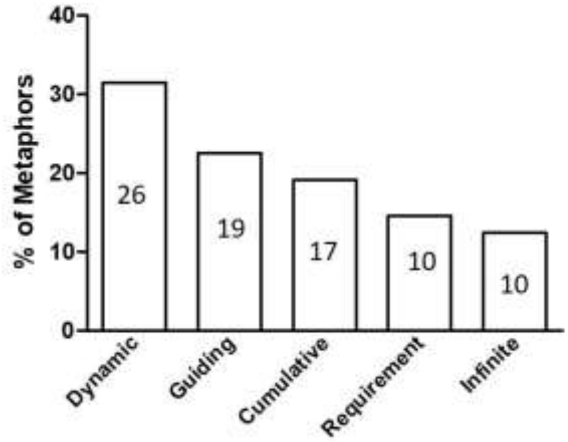



Figure 3. A graphical representation of Table 5. Metaphor percentages in each category. Numbers in the bars give the metaphor count fort hat category.

The categories, according to their representation rates, are; dynamic, guiding, cumulative, requirement and infinite, respectively, and they are discussed separately below. In some cases in which the category of the metaphor was not obvious, the explanation was considered as the determining factor. Therefore, the same metaphors could be represented in different categories for such cases.

*Category 1- Dynamic:* In this category, which consists of metaphors expressing the dynamic dimension of science, 26 metaphors were produced. Metaphors produced by the participants are smartphone, masterpiece, baby, desert, sea, earthquake, nature, adaptation of nature to technology, being born, a whirling entity, world, evolution, our life, pencil and eraser, library, matryoshka, wonder, seasons, fashion, river, ocean, bus, water, technology, years and road. This category, which covers 31.46% of the metaphors created, is the category with the highest number of metaphors. More than one person expressed nature and road. Examples of metaphor expressions produced by the pre-service teachers (PT) for the dynamic category are as follows:

*PT-44: "Science is like water. Because it is a flowing process, it pierces through the obstacles and reaches a conclusion. People benefit from it and gain information."*
*PT-171: "Science is like an earthquake. Because, like an earthquake, when science emerges (facts in science), nothing will be the same as before. Some places also need radical changes. Shocking and surprising, both are unknown when an earthquake will occur, and it is unknown when science will reveal the truth."*
*PT-209: "Science is like fashion. Because it is constantly changing. Like fashion, it can change when a new idea comes to mind and is expressed properly."*

*Category 2- Guiding:* Metaphors expressing that science is a guide are a kidney, great events, living together with nature, the door to the world, education, the universe, the union of philosophy and humanity, the sun, the sun's rays, the building block of our life, light, enlightenment with light, human, book, torch, magic wand, technology, technological tools, rain. It covers 22.47% of the metaphors produced. Some of the metaphor expressions produced by the pre-service teachers for the guiding category are as follows:
*PT-24: "Science is like a torch that lights our way in the dark. Because science is the one that enlightens us and guides us when we are in darkness, knowing nothing."*
*PT-147: "Science is like a book. Because, just as every page of a book provides new information, science contains a broad range of knowledge, and it enlightens us like a book in the light of this information.. As we go deeper into the book, it gains meaning in our minds, and as we go deeper into science, we make better sense of it, we learn and discover better."*
*PT-156: "Science is like the rays of the sun. Because just like the sun illuminates the world, it creates new concepts in our minds. In the light of science and new technological developments, it makes us more equipped individuals. Just as there would be no science without the sun, it is not possible for us to continue our lives without science."*
*PT-155: "Science is like a kidney. Because science has contributed a lot to human life, it has allowed people to do bigger things with less force and less energy. I compared science to a kidney because a person can survive with one kidney, but compared to a person with both kidneys, some features are limited or take a long time to be done. Similarly, in science; life exists without it, but it provides a serious degree of convenience in its existence."*

*Category 3- Cumulative:* In this category, which expresses that science is cumulative, 17 different metaphors were used. These metaphors are watering a tree, plant, magic, a flowering path, child, experiment, climbing a wall, earth, sapling, planet waiting to be discovered, book, penny bank, machine, matryoshka, juice, history, pile. It includes 19.10% of all the metaphors created. One participant produced each metaphor. Some of the metaphor expressions produced by pre-service teachers for the cumulative category are as follows:
*PT-64*: *"Science is like a penny bank. Because in the sub-branches of science, knowledge accumulates over centuries and shows progress. Information is cumulative. While developing a new theory, law or invention, they benefit from previous knowledge and emerge in the light of this information."*
*PT-105: "Science is like a constantly growing plant. Because research and interests continue to develop in the same way, we take care of a plant, water it and take care of it, and its development takes place when we take care of science in the same way."*
*PT-190: Science is like a child. Because they learn something new every day, puts new information on it, synthesizes them and uses this information in his/her future life. In this context, it is an effort to learn something new by taking and evaluating new information in science, putting new information on it or ignoring a piece of information."*

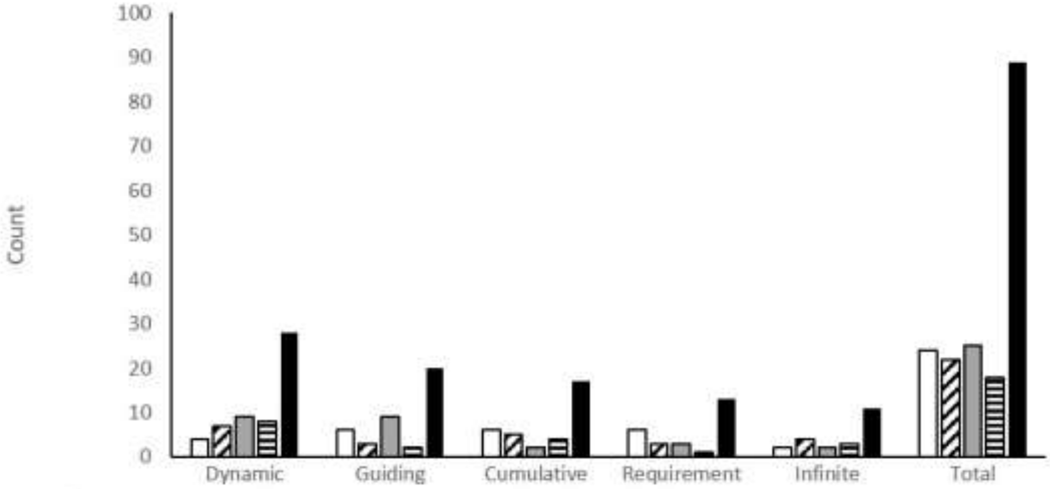
*Category 4- Requirement:* Metaphors expressing the requirement dimension of science are family, mother, complement of nature, sun, essence of life, basis of life, organ, water, basic need, and puzzle pieces. 3 people have expressed the basis of life. 10 different metaphors, constituting 14.6% of the metaphors, were produced. Some of the metaphor expressions produced by the pre-service teachers for the requirement category are as follows:
*PT-5: "Science is like a mother. Because we need it in every moment of our lives, there is always something missing somewhere."*
*PT-74: "Science is like the sun. Because as long as there is no blocker, like the cloud that blocks the sun, it is equal to everyone. Anyone who wants it, can get it. It is like the sun that cannot be lived in its absence."*
*PT-137: "Science is like water. Because just as life without water, life without science is unimaginable."*

*Category 5- Infinite:* In this category, which consists of metaphors expressing that science is infinite, 10 different metaphors have been produced, such as tree, child's questioning of the universe, sea, nature, cycle, universe, exploring the universe, cave, ocean, life itself. It covers 12.35% of all the metaphors. Some of the metaphor expressions that pre-service teachers produced for the infinite category are as follows:
*PT-2: "Science is like exploring the world and the entire universe. Because science will start with the birth of the universe and continue until the end."*

*PT-65: "Science is like an endless cave. Because there are always new ways, new discoveries, we can get lost in science. We can go different ways. There is also the dark side that is not revealed. waiting to be discovered."*
*PT-189: "Science is like the universe. Because knowledge and science have no limitations, today, science is developing day by day and multiplying endlessly. Even if humanity has perished, science will never perish. Science is limitless and continues to expand like the universe."*

**The Relationship Between Perception of Science and Class Levels of Pre-service Science Teachers**

To determine the relationship between the metaphors created by the pre-service science teachers and their grade levels, a cross-table was created and expressed graphically (see figure 4). Pre-service teachers produced the highest amount of metaphors in the dynamic category. While those who express science as dynamic are mostly third-grade participants, those who express it least are first-grade participants. The guiding category was expressed at the highest level by third-grade participants and at the lowest level by fourth-grade participants. The cumulative category was stated by the first-graders at their highest level and the third-graders at their lowest level. First-grade teacher candidates had the highest requirement category, while fourth-grade teacher candidates had the lowest.The lowest number of metaphors was produced in the infinite category. In this category, the first and third grades produced the lowest number of metaphors, while the second grade teacher candidates expressed this category of metaphors at the maximum level.




| | Dynamic | Guiding | Cumulative | Requirement | Infinite | Total |
|---|---|---|---|---|---|---|
| Grade 1 | 4 | 6 | 6 | 6 | 2 | 24 |
| Grade 2 | 7 | 3 | 5 | 3 | 4 | 22 |
| Grade 3 | 9 | 9 | 2 | 3 | 2 | 25 |
| Grade 4 | 8 | 2 | 4 | 1 | 3 | 18 |
| Category total | 28 | 20 | 17 | 13 | 11 | 89 |

Figure 4. Relationship between the metaphor categories and class levels of pre-service science teachers.

First-year pre-service teachers expressed science as more cumulative, requirement, and guiding. Metaphors in which science is expressed as cumulative and requirement are mostly created at this class level. Metaphors in which science is expressed dynamically were formed at least at this grade level. On the other hand, second-grade teacher candidates expressed science more dynamically. Metaphors expressing science as infinite were created mostly at this grade level. Third-grade teacher candidates created 9 metaphors for science as dynamic and guiding, and the highest number of metaphors represented in a category emerged at this grade level. Metaphors expressed at minimum level are cumulative and at maximum level are guided bythird-grade teacher candidates. Fourth-grade pre-service science teachers expressed science mostly as dynamic. Among the metaphors obtained at this level, requirement and guiding are represented at the lowest level.

Using the cross table in figure 3, the relationship between the grade levels and the metaphors categories was analyzed. Fisher-Freeman-Halton analysis was considered since the data did not meet the chi-square assumptions. Fisher's exact test p-value was 0.339 ($p>0.05$). Although there seems to be an increasing trend for the dynamic and a decreasing trend for the requirement category with increasing grade levels, no statistically significant relationship was found between the grade levels and the metaphors used.

**The Relationship Between the Perception of Science and Views on the Nature of Science**

The scores obtained from VNOS-C questionnaire were summed up and divided into unacceptable, partially acceptable, and acceptable categories. According to the data obtained from 89 participants, 44 participants had an unacceptable opinion, while 45 participants had a partially acceptable opinion None of the participants expressed an acceptable opinion. The relationship between the 5 categories created from the metaphors expressed by the participants and the nature of science categories was analyzed using the Chi-square independence test. (see Table 6).

Table 6. Chi-square analysis for the relationship between science perception and views on the nature of science

| | | Nature of science categories | | | |
|---|---|---|---|---|---|
| **Metaphor Categories** | **n** | **Unacceptable** | **Partially acceptable** | $x^2$ | **P** |
| Dynamic | 28 | 14 | 14 | 1,302 | ,861 |
| Guiding | 20 | 10 | 10 | | |
| Cumulative | 17 | 7 | 10 | | |
| Requirement | 13 | 8 | 5 | | |
| Infinite | 11 | 5 | 6 | | |
| Total | 89 | 44 | 45 | | |

The null hypothesis used here states that pre-service science teachers' VNOS-C levels and perceptions of science are independent.. According to the results, there is no statistically significant relationship between the prospective science teachers' views on the nature of science and their perceptions of science [ x_2^2 = 1,302, p > 0,05].

Table 6 data is given as a histogram graph in figure 5. The majority of the participants, whose views on the nature of science were unacceptable and partially acceptable, expressed science as dynamic. Participants who expressed unacceptable views about the nature of science expressed science as dynamic, guiding, requirement, cumulative and infinite, in descending order. Participants who expressed partially acceptable views on the nature of science expressed science as dynamic, guiding, cumulative, infinite, and requirement, in descending order. Participants who expressed an unacceptable view about the nature of science stated science the least as infinite, and those who expressed a partially acceptable view stated science the least as a requirement.

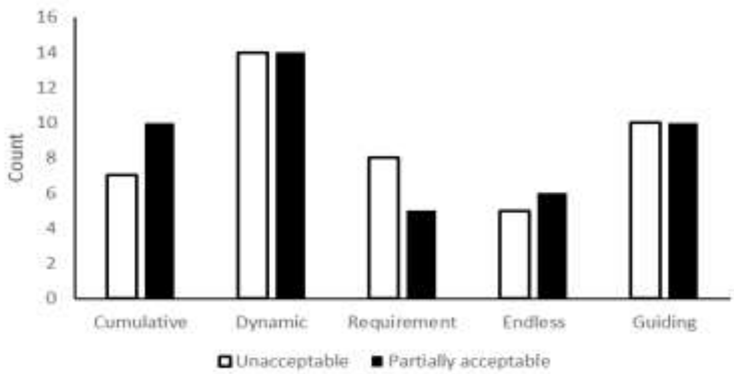



Figure 5. The relationship between views on the nature of science and perception of science

**Discussion**

According to the findings obtained from the VNOS-C questionnaire, pre-service science teachers' views on the nature of science are unacceptable and partially acceptable, independent of their grade level. This result is consistent with the study conducted by Erdaş et al. (2016), which examines the articles and theses on views of the nature of science between 1998-2012 in our country. In addition, similar results were found in studies conducted with science teachers and teacher candidates (Aslan et al., 2009; Aydemir et al., 2017; Yenice and Ceren Atmaca, 2017). The fact that the nature of science subject is included only in the Nature and History of Science course and that students' inability to make connections with other course contents or daily knowledge may have affected the pre-service teachers' inadequate vision. The data in our study were collected in the fall semester of the 2019-2020 academic year. The nature of science course is given in the spring semester of the third year. Even if the fourth grade students took the course, they did not succeed in acceptable results. Therefore limited knowledge of NOS cannot be attributed to whether or not they took the course according to our study. Although the sub-dimensions of the nature of science are found in different courses at the undergraduate level starting from the first year, it may be difficult for students to realize them. Because it is difficult for every student to have skills such as receiving, connecting and interpreting information that is not clearly expressed. The nature of science issues is given little coverage in teacher education in Turkey (Çakıcı, 2009), so it is necessary to provide opportunities for them to take part in different activities related to the nature of science in undergraduate education. In addition, a number of researchers stated that science teachers' views about the nature of science were insufficient and do not include it in their classrooms because they could not integrate it with science content (McComas, 2017; Mesci, 2020; Neumann et al., 2020). This may lead to the fact that individuals, whom we expect to be well-equipped students about the nature of science starting from primary education, do not have the desired level of knowledge.

In this research, pre-service teachers' views were analyzed according to the classical understanding of the nature of science. According to the results, pre-service science teachers' views on the nature of science tend to increase in a positive manner with undergraduate education. In a study conducted by Özbudak Kılıçlı and Polat (2015), pre-service science teachers' inadequate knowledge and misunderstanding before taking the Nature of Science and History of Science course have increased to an acceptable and sufficient level at the end. The positive effect of the Nature and History of Science course on the development of views on the nature of science was also mentioned in different studies (Özdemir and Akçay, 2009; Yenice and Ceren Atmaca, 2017). Understanding the nature of science was shown to be improved by applying different techniques and methods during the undergraduate process (Akerson et al., 2013; Cengiz and Kabapınar, 2017; Mesci, 2020; Tsybulsky, 2018; Williams and Rudge, 2019). As a result, during the undergraduate period, courses and activities other than the Nature and History of Science course have an impact on the development of perspectives on the nature of science.. These data are consistent with the results of our study. In another study, social studies teacher candidates stated that the nature of science was included in undergraduate courses, but the definition, methods and benefits of science were more dominant. They knew the concepts such as science and scientific knowledge, but had difficulty in defining them In addition, grade levels did not affect their views and they had some misconceptions (Çınar and Köksal, 2013). Therefore, including the nature of science in undergraduate education may not always reflect teacher candidates' views at the desired level.

When all dimensions of the nature of science are examined, the pre-service teachers who stated the most unacceptable opinions in the dimensions of tentativeness, empirically-based, observation and inference, theory-laden, imagination and creativity were the third grade students. Although our research was carried out on a voluntary basis, the participants' opinions may not have been fully reflected due to factors such as the distraction of the participants during data collection and the time period of the survey. When the undergraduate levels are considered, the views on the nature of science, in general, tend to increase, but a decrease was noticed in the third grade.

Only a small percent of the participants gave an acceptable answer to the question "What is science?" and the majority reported an unacceptable opinion. In a study carried out by Doğan Bora (2005), physics, chemistry, biology teachers and high school students were asked about the definition of science, and they were divided into categories as realistic, acceptable and inadequate. 20% of the teachers and the students gave realistic answers for the definition of science. Most students expressed science as a tool, while teachers expressed it as a social activity. In a study conducted by Çınar and Köksal (2013) with social studies teacher candidates, the participants were found to know what science was but could not fully explain it. They expressed the characteristics of science rather than the definition of science.

Similarly, in a study conducted with the 4th Science Education Congress participants in Turkey, the majority has expressed science as a community of knowledge (Türkmen and Yalçın, 2001). The literature and the results obtained in our study show that students, pre-service teachers and teachers cannot fully define science. Although science is a very basic concept and is known by everyone, the difficulty in defining it may stem from the inability of individuals to express their knowledge in writing. Therefore, the data collected through metaphors is of importance.

According to the results, the most commonly used metaphors were nature, the universe, the basis of life, water and technology. Although similar results were found in other studies, different concepts were also preferred (Çavaş et al., 2019; Özgün et al., 2018; Şenel and Aslan, 2014). This shows that metaphors can meet at a common point and change from person to person. The categories created with metaphor analysis are dynamic, guiding, cumulative, requirement, and infinite. This result is similar to other studies carried out with different samples (Bıyıklı et al., 2014; Çavaş et al., 2019; Kösem, 2017; Özgün et al., 2018; Şenel and Aslan, 2014). Although the metaphors produced by the pre-service science teachers are not wrong, some deficiencies are observed. Perceptions such as science has a cumulative structure, has no borders and provides guidance are correct, but the fact that no metaphors were produced for the universality of science and that science includes a process, shows that perceptions of science are not very comprehensive. This also correlates with the answers to the "What is science?" question of VNOS-C questionnaire. The lack of expected answers to this question probably has resulted from the insufficiencies in science perception of the pre-service teachers. The fact that science teacher candidates took fewer science-related courses in undergraduate education may have contributed to their correct but incomplete science perceptions. In addition, the education they received before the university and the personal views they formed depending on environmental conditions such as social media and family probably had a major impact since the perceptions are formed as a result of a certain process. When the metaphors in the infinity (PT-189, "Even if humanity disappears, science will never perish."),and guiding (PT-156 "Because, just as the sun illuminates the world, we also create new concepts in our minds in the light of science and new technological developments, making us better-equipped individuals") categories are examined, we have realized misconceptions such as 'science is independent of humans' and' technology and science are same', respectively. In a study conducted by Kösem (2017), primary school teacher candidates expressed technology as a branch of science. The fact that pre-service teachers do not express technology due to science shows that they cannot fully discriminate the two concepts. When all metaphors and categories are examined, we can conclude that pre-service science teachers have a positive perception for science. Similar to other studies, although the participants do not have a comprehensive perception of science, they generally have a positive perception for science (Çavaş et al., 2019; Kösem, 2017; Şenel and Aslan, 2014).

According to the results obtained, no statistically significant relationship was found between the metaphors of teacher candidates and their grade levels. In other studies in which perceptions of the concept of science are determined, a relationship between the grade levels and the perception of science were shown (Bıyıklı et al., 2014; Çavaş et al., 2019; Özgün et al., 2018). It is not possible to score categories according to a low- or high-level scoring system in such studies. As can be seen from the metaphors used by the participants and the categories created accordingly, these types of metaphors can only be categorized as positive/negative, sufficient/inadequate and lose their details in statistical analysis. Although there was no statistical difference between grade levels in our study, the difference of perception of science between grade levels is distinguishable. While first-year science teacher candidates expressed science mostly as cumulative (f:6), requirement (f:6) and guiding (f:6), fourth grades expressed it as dynamic (f:8). Furthermore, fourth-year pre-service teachers cited science as a requirement and guidance as an uncommon occurrence. Indeed, this finding demonstrates that students' attitudes toward science alter as they progress through the grades.

In order to determine whether there is a relationship between science teacher candidates' perception of science and their views on the nature of science, statistical methods were primarily applied and no significant relationship was found. As mentioned before, the power of statistical analyses decreases due to the excess of categories used in the study. Since combining the categories in the same group would lead to data loss, this option was not preferred in this study. When the results of content analysis were examined, the answers given by the science teacher candidates to the tentativeness dimension of the nature of science are unacceptable. However, they expressed science mostly as dynamic in the perception of science questionnaire. The fact that the participants could not fully express themselves or could not make sense of the question correctly may have been reflected in the results as an unacceptable view. These results indicate the importance of using different data collection tools to support the findings, which otherwise would result in misleading conclusions.

## Conclusion

Today, the interest and need for science are increasing and its effects are seen in all areas of human lives. The science perceptions of teacher candidates, who will raise future individuals, maintain its importance. The nature of science, has an important part in science teaching, as well as in raising conscious citizens. As a result, this study looked into the perspectives of pre-service science instructors on the nature of science and their conceptions of science..

According to the results, pre-service science teachers' views about the nature of science are unacceptable and partially acceptable. Their opinions show an increasing trend throughout their undergraduate education. It has been noticed that undergraduate education has a positive effect on the opinions of teacher candidates, but it is not at the desired level. Therefore, apart from the Nature andHistory of Science course in education faculties, the nature of science should be taught beginning from the first year through different courses.

Pre-service science teachers have unacceptable views in the dimensions of nature of science, tentativeness, empirically-based, observation and inference, theory and law, imagination and creativity. They have acceptable views in terms of theory-laden and socio-cultural impact. When the dimensions of the nature of science are examined, it is known that students, teacher candidates, and teachers have difficulties in some subjects. In particular, these dimensions should be emphasized more and using different teaching methods and techniques is recommended.

When the science perceptions of science teacher candidates were examined, some deficiencies and misconceptions were observed. Their perceptions were positive but not very comprehensive. No statistical relationship between science perception and grade levels was observed, but their perceptions were changed in the content analysis. Science perceptions and views of nature of science were not statistically correlated; however, metaphor content analysis could explain some of the discrepancies seen in the results for the views of the natüre of science.

## Recommendations

The nature of science content should be adopted by educators and integrated into textbooks, lessons and assessments. However, this isn't easy to implement because most teacher education programs offer little information on the nature of science and how to teach it (McComas, 2017). Since teachers teach their lessons according to the education programs, clearly expressing the achievements of the nature of science in the program will help the teachers in the course process (Şardağ vd., 2014). As a result, the nature of science and pedagogical content knowledge should complement one another, science teacher education programs should be reconsidered, and teachers should be able to create activities that teach the nature of science and reflect the subject's value (Clough vd., 2020).

- The data obtained using the Views on the Nature of Science Questionnaire in this research were analyzed according to Lederman's seven sub-dimensions. Alternative approaches such as Family Resemblance Approach could be considered for the future studies.
- Longitudinal studies can be carried out to determine the factors affecting teacher candidates' views.
- How pre-service teachers convey their views to their students in the classroom environment during the in-service period can also be investigated.
- Science teacher candidates' perceptions about the concept of science were determined through metaphors. Different data collection tools and methods can be preferred to determine the factors affecting the results and perform in-depth analyses.

## Notes

This manuscript was produced from the master's thesis study of Betül Erçelik.

## Author (s) Contribution Rate

The application of the instruments, preliminary data analysis was conducted by Betül Erçelik. Main data analysis, statistical analysis was conducted by Aslı Sade Memişoğlu. Manuscript was written by both authors.

## Conflicts of Interest

Authors declare no conflict of interest.

## Ethical Approval

Ethical permission (01/11/2019 - 2739) was obtained from Institute of Eduational Sciences, Dokuz Eylul University for this research.

## References

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

Aikenhead, G. S. (1988). An analysıs of four ways of assessıng student belıefs about sts topıcs. 25(8), 607–629.

Akerson, V., Nargund-Joshi, V., Weiland, I., Pongsanon, K., & Avsar, B. (2013). What Third-Grade Students of Differing Ability Levels Learn about Nature of Science after a Year of Instruction. International Journal of Science Education, 36(2), 244–276.

Arslan, M. M., & Bayrakcı, M. (2006). Metaforik Düşünme ve Öğrenme Yaklaşımının Eğitim-Öğretim Açısından İncelenmesi. Milli Eğitim, 35(171), 100–108.

Aslan, O., Yalçın, N., & Taşar, M. F. (2009). Fen ve Teknoloji Öğretmenlerinin Bilimin Doğası Hakkındaki Görüşleri. Ahi Evran Üniversitesi Eğitim Fakültesi Dergisi, 10(3), 1–8.

Aydemir, S., Kazanç, S., & Karakaya Cırıt, D. (2017). Fen Bilgisi Öğretmen ve Öğretmen Adaylarının Bilimin Doğasına İlişkin Görüşlerinin Araştırılması. Turkish Journal of Educational Studies, 3(3).

Bayır, E. (2016). Fen Bilimleri Öğretmenlerinin Bilimin Doğasına İlişkin Görüşleri: Bilişsel Harita Örneği. Kastamonu Eğitim Dergisi, 24(3), 1419–1436.

Bıyıklı, C., Başbay, M., & Başbay, A. (2014). Ortaokul ve Lise Öğrencilerinin Bilim Kavramına İlişkin Metaforları. Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 14(1).

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, E. Ö., Karadeniz, Ş., & Demirel, F. (2018). Bilimsel Araştırma Yöntemleri. Pegem Akademi.

Creswell, J. W. (2012). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th ed.). Boston, MA: Pearson.

Çakıcı, Y. (2009). Fen Eğitiminde Bir Önkoşul: Bilimin Doğasını Anlama. Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 29, 57–74.

Cameron, L. (2002). Metaphors in the Learning of Science : A discourse focus. British Educational Research Journal, 28(5), 673–688.

Çavaş, P., Çetin, G., Palabıyık, E., & Çavaş, B. (2019). Öğretmen Adaylarının Bilim ve Teknolojiye Yönelik Algılarının Metaforlar Yardımıyla Ortaya Konulması. Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 13(2), 1239–1270.

Cengiz, C., & Kabapınar, F. (2017). Dolaylı fen öğretiminde hizmet öncesi argümantasyon eğitiminin öğretmen adaylarının bilimin doğasını kavramalarına etkisi. Turkiye Kimya Dernegi Dergisi Kisim C: Kimya Egitimi, 2(1), 19–62.

Çınar, M., & Köksal, N. (2013). Sosyal bilgiler öğretmen adaylarının bilime ve bilimin doğasına yönelik görüşleri. Mersin Üniversitesi Eğitim Fakültesi Dergisi, 9(2), 43–57.

Clough, M. P., Herman, B. C., & Olson, J. K. (2020). Preparing Science Teachers to Overcome Common Obstacles and Teach Nature of Science. In W. F. Mccomas (Ed.), Nature of Science in Science Instruction (pp. 239–251). Springer.

Doğan Bora, N. (2005). Türkiye Genelinde Ortaöğretim Fen Branşı Öğretmen ve Öğrencilerinin Bilimin Doğası Üzerine Görüşlerinin Araştırılması. (Unpublisheddoctoral dissertation), Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara.

Doğan, N., Çakıroğlu, J., Çavuş, S., Bilcan, K., & Arslan, O. (2011). Öğretmenlerin bilimin doğası hakkındaki görüşlerinin geliştirilmesi: Hizmetiçi eğitim programının etkisi. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 40(40), 127–139.

Edmondson, E., Stephen, B., Dina, T., & Jennifer, M. (2020). Learning Aspects of Nature of Science Through Authentic Research Experiences. In W. F. Mccomas (Ed.), Nature of Science in Science Instruction (pp. 659–673). Springer.

Emran, A., Spektor-levy, O., Paz Tal, O., & Ben Zvi Assaraf, O. (2020). Understanding Students' Perceptions of the Nature of Science in the Context of Their Gender and Their Parents' Occupation. Science and Education, 29(2), 237–261.

Erdaş, E., Doğan, N., & İrez, S. (2016). Bilimin Doğasıyla İlgili 1998-2012 Yılları Arasında Türkiye'de Yapılan Çalışmaların Değerlendirmesi. Kastamonu Eğitim Dergisi, 24(1), 17–36.

Fraenkel, J. R., & Wallen, N. E. (2011). How to design and evaluate research in education (8th ed.). New York:McGraw-Hill.

Jakobson, B., & Wickman, P. (2007). Transformation through Language Use : Children ' s Spontaneous Metaphors in Elementary School Science. Science & Education, 16, 267–289.

Kaya, E., Erduran, S., Akgün, S., & Aksöz, B. (2017). Öğretmen Eğitiminde Bilimin Doğası: Bütünsel Bir Yaklaşım. Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 11(2), 464–501.

Kösem, Ş. (2017). Öğretmen adaylarının bilim ve teknoloji konularındaki metaforik algıları. International Congress Of Eurasian Social Sciences, 8(28), 1–20.

Lederman, N. (2007). Nature of Science: Past, Present, and Future. Handbook of Research on Science Education, 831–880.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, 29(4), 331–359.

McComas, W. (2017). Understanding how science works: UnderstaThe nature of science as the foundation for science teaching and learning. School Science Review, 98(365), 71–76.

Mccomas, W. F., Clough, M. P., & Almazroa, H. (1998). The Nature of Science in Science Education. In The Nature of Science in Science Education.

Mesci, G. (2020). The Influence of PCK-Based NOS Teaching on Pre-service Science Teachers' NOS Views. Science and Education, 29(3), 743–769.

Miles, M. B., & Huberman, A. M. (1994). Qualitative data analysis: An expanded sourcebook. sage.

Neumann, I., Michel, H., & Nikos, P. (2020). Blending Nature of Science with Science Content Learning. Nature of Science in Science Instruction (327–342). Springer.

Niebert, K. & Gropengieße, H. (2014). Understanding the Greenhouse Effect by Embodiment – Analysing and Using Students' and Scientists' Conceptual Resources. International Journal of Science Education, 36:2, 277-303.

O'Connor, C., & Joffe, H. (2020). Intercoder Reliability in Qualitative Research: Debates and Practical Guidelines. International Journal of Qualitative Methods, 19, 1–13.

Ocak, İ., & Yeter, F. (2018). 2006 – 2016 Yılları Arasında Çalışılmış "Bilimin Doğası" Konulu Ulusal Tez ve Makalelerin İncelenmesi. Kuramsal Eğitimbilim Dergisi, 11(3), 522–543.

Özbudak Kılıçlı, Z., & Polat, F. (2015). Fen Bilimleri Öğretmen Adaylarının Bilimin Doğasını Anlama Düzeylerinin Tespit Edilmesi (VNOS-C). The Journal of Academic Social Science Studies, 431–444.

Özcan, H. (2013). Fen bilgisi öğretmen adaylarının fen içeriği ile ilişkilendirilmiş bilimin doğası konusundaki pedagojik alan bilgilerinin gelişimi. (Unpublished doctoral dissertation). Eğitim Bilimleri Enstitüsü, Gazi Üniversitesi, Ankara.

Özcan, H., & Taşar, M. F. (2018). Öğretmen Adaylarının Bilimin Doğası Anlayışlarının Değerlendirilmesine Yönelik Bir Dereceli Puanlama Anahtarı Deseninin Geliştirilmesi. Online Fen Eğitimi Dergisi, 3(2), 35–46.

Özdemir, G., & Akçay, H. (2009). Bilimin Doğası ve Bilim Tarihi Dersinin Öğrencilerin Bilimin ve Bilimsel Bilginin Doğasına İlişkin Düşüncelerine Etkisi. Education Sciences, 4(1), 218–227.

Özgün, B. B., Gürkan, G., & Kahraman, S. (2018). Öğretmen Adaylarının Bilim ve Bilim İnsanı Kavramlarına İlişkin Algılarının Metafor Analizi Aracılığıyla İncelenmesi. İnönü Üniversitesi Eğitim Fakültesi Dergisi, 19(2), 204–225.

Pitcher, R. (2011). Doctoral Students' Conceptions of Research. The Qualitative Report, 16(4):971-983.

Pope, M. L., & Gilbert, J. K. (1983). Explanation and metaphor: Some empirical questions in science education. European Journal of Science Education, 5(3), 249–261.

Rusznyak, L., & Walton, E. (2014). Using metaphors to gain insight into South African student teachers' initial and developing conceptions of 'being a teacher.' Education as Change, 18(2), 335–355.

Saban, A. (2008). Okula ilişkin metaforlar. Kuram ve Uygulamada Egitim Yönetimi Dergisi, 14(3), 459–496.

Saban, A. (2009). Öğretmen Adaylarının Öğrenci Kavramına İlişkin Sahip Oldukları Zihinsel İmgeler. Türk Eğitim Bilimleri Dergisi Bahar, 7(2), 281–326.

Saribas, D., & Ceyhan, G. D. (2015). Learning to teach scientific practices: Pedagogical decisions and reflections during a course for pre-service science teachers. International Journal of STEM Education, 2(1), 1.

Şardağ, M., Aydin, S., Kalender, N., Tortumlu, S., Çiftçi, M., & Perihanoğlu, Ş. (2014). Bilimin doğasi'nin ortaöğretim fizik, kimya ve biyoloji yeni öğretim programlarinda yansitilmasi. Egitim ve Bilim, 39(174), 233–248.

Seung, E., Park, S., & Narayan, R. (2011). Exploring Elementary Pre-service Teachers' Beliefs About Science Teaching and Learning as Revealed in Their Metaphor Writing. Journal of Science Education and Technology, 20(6), 703–714.

Thomas, L., & Beauchamp, C. (2011). Understanding new teachers' professional identities through metaphor. Teaching and Teacher Education, 27(4), 762–769.

Tsai, C. C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. International Journal of Science Education, 24(8), 771–783.

Tsybulsky, D. (2018). Comparing the Impact of Two Science-as-Inquiry Methods on the NOS Understanding of

High-School Biology Students. Science and Education, 27(7–8), 661–683.
Türkmen, L., & Yalçın, M. (2001). Bilimin Doğası ve Eğitimdeki Önemi. Education, 72, 19–40.
Unal Coban, G. (2010). The scientific understanding level of prospective science teachers. Journal of Baltic Science Education, 9(3), 237–254.
Williams, C. T., & Rudge, D. W. (2019). Effects of Historical Story Telling on Student Understanding of Nature of Science. Science and Education, 28(9–10), 1105–1133.
Yenice, N., & Ceren Atmaca, A. (2017). Fen Bilgisi Öğretmen Adaylarının Bilimin ve Bilimsel Bilginin Doğasına Yönelik Bilgi ve Görüşlerinin Belirlenmesi. Kuramsal Eğitimbilim Dergisi, 10(4), 366–393.
Yıldırım, A., & Şimşek, H. (2018). Sosyal Bilimlerde Nitel Araştırma Yöntemleri. Seçkin Yayıncılık.
Zheng, H., & Song, W. (2010). Metaphor Analysis in the Educational Discourse: A Critical Review. US-China Foreign Language, 8(9), 42–49.