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Students' Nature of Science Understandings: A Phenomenological Study

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Abstract
The efforts shown in recent years related to the reform movements in science education have focused on the assertion that informed nature of science understandings (NOS, hereafter) should be developed. In line with this idea, NOS has become the central component of numerous science curricula. In the study, therefore, it was aimed to determine science education master students' NOS understandings. The study was conducted in a state university in Turkey during the fall semester of the 2019-2020 academic year and included six science education master students who had taken science methods course. The data were collected through interviews and analyzed by content analysis under phenomenological method. As a result, the students had various and mixed understandings related to the definition of science and characteristics of scientific knowledge. In addition, it was observed that the students handled science with a narrow scope, that they had difficulty in the distinction between theory and law, and that they could not develop informed understandings in the component of theory-laden NOS. In light of these results, the implications and the directions for further study were provided.

Keywords: Graduate Students, Nature of Science, Phenomenology, Science Education

1. Introduction

The main purpose of science education is to raise scientifically literate individuals who actively participate in the construction process of scientific knowledge. One of the most important components of scientific literacy is NOS. There are many definitions of NOS. What is meant by understanding NOS is making sense of what science is and how it functions, what the relationship between science and society is, and the epistemological and ontological foundations underlying scientific activities that form these relations (Clough, 2006). In other words, NOS refers to "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge" (Abd-El-Khalick et al. 1998, p. 418). Instead of putting forward a definition of NOS that will be accepted by everyone, it would be more rational to mention a few components that stand out. Considering that NOS can be taught at K-12 level, it has become important to identify the components of NOS teaching. While empirical, tentative, inferential, creative, and theory-laden are the essential components (Lederman, 1999), scientific method and theory-law are additional components (Abd-El-Khalick & Akerson, 2004; Lederman, 2007).

Empirical NOS is based on the assumption that science depends on observations related to the natural world. These observations are made through phenomena. However, we cannot directly have access to these phenomena. Evidence is collected through the methods of accessing the phenomenon such as experiment and measurement. It is possible that new evidence or re-interpreted evidence can support or falsify current theories. When compared with other methods, it is assumed that scientific method produces the most valid evidence. These characteristics of science separate it from other disciplines such as religion and philosophy. It is the component that has the most important role in the debate over what the boundaries of this distinction will be (Lederman et al. 2002). Tentative NOS, on the other hand, means that scientific knowledge can change through new evidence or re-interpreting current evidence. Scientific knowledge types, as well as scientific laws, are open to change. Tentativeness of scientific knowledge is directly related with empirical NOS, because this characteristic of scientific knowledge depends on the presence or re-interpretation of evidence (Lederman, 1999).

Inferential NOS involves judgements that are made over descriptive expressions related to directly observable phenomena. Creative NOS is based on the assumption that science is not an activity that is totally based on reason and sequential. Theory-laden NOS argues that scientific knowledge cannot be thought separately from scientists. Scientific knowledge is affected by bias, experiences, the values of their society, and expectations of scientists. Therefore, science never starts with objective observations (Abd-El-Khalick et al. 1998).

In order for teachers to effectively teach NOS through these components, they should firstly be aware of their NOS understandings (Capps et al. 2012; Southerland et al. 2006). It is important that teachers have informed NOS understandings, because these understandings support students in their making decisions based on scientific knowledge in their decision-making processes (Cullinane & Erduran, 2022; Khishfe, 2012). However, science teachers may not hold clear ideas about NOS (Morrison et al. 2009). Previous research has shown that both students and teachers have inadequate NOS understandings. It is noteworthy that these studies were conducted basically with teacher candidates (Abd-El-Khalick, 2005; Akerson et al. 2006; Cullinane & Erduran, 2022; Duruk & Akgun, 2020; Duruk et al. 2019; Karisan & Cebesoy, 2018; Mesci & Schwartz, 2017) and with students (Kampourakis, 2016; Khishfe & Abd-El-Khalick, 2002; Park et al. 2014; Voss et al. 2022). To the best of our knowledge, studies that examined NOS understandings of science education master students' who are likely to be the scientists of the near future are very few. Therefore, it was aimed in the present study to determine NOS understandings of these students. In line with this purpose, we framed the following research questions:

1. What are the understandings of the students related to science?
2. What are the understandings of the students related to the characteristics of science?

2. Method

2.1 Research Design

Phenomenology was the method of the study. Phenomenology is a qualitative research pattern that helps us to deeply understand the experiences of people who are involved in the event and experienced the facts one-to-one (Yin, 2016). Phenomenological science studies may not reveal definite and generalizable results that are appropriate for the nature of qualitative research. However, it can yield examples, explanations, and experiences that will provide results which will helps us better understand a phenomenon. With this aspect, it significantly contributes to both scientific field and literature (Yıldırım & Simsek, 2016).

2.2 Study Group

The study included six science education master students who had taken science methods course. The study group was determined through convenience sampling, which is one of the purposeful sampling methods. All students were female.

2.3 Data Collection

Interview is a frequently used data collection method in qualitative studies. Creswell (2019, p. 127) has defined one-on-one interviews as “interviews that are used when personal perspectives of participants are needed.” In such interviews, changes in the interviewees’ body language and tones can be seen easily and a personal connection can be established. In one-on-one interviews, it is recommended to list the questions and prepare an interview log to record some parts of the author’s opinions in the interview process (Creswell, 2019, p.127-132). The interview log prepared for the study consisted of introduction, beginning, and content questions.

While preparing the interview form, firstly, the literature was reviewed and similar studies were examined. Then, by benefiting from interview questions used in similar studies, questions were prepared by the second author. The interview form included questions related to science and NOS. The interview form prepared in order to identify students’ NOS understandings consisted of two parts. In the first part, there were questions on personal information while the second part included questions on NOS understandings. Each student was given separate codes from P1 to P6 and they were identified with these codes throughout the study.

2.4 Data Analysis

Content analysis was performed during the analysis of the data. Content analysis is based on “bringing similar data together within the framework of certain concepts and themes and interpreting them to make them understandable by the reader” (Yıldırım & Simsek, 2016). In order to ensure integrity, the recordings made through the interviews were translated verbatim. Transcribed data were read, and meaningful data units were determined. By creating codes from the determined data units, a list of codes was prepared. Each interview question was handled as a theme, and the codes were associated with these themes. The second author analyzed the data. The first and the third authors conducted a blind round of analysis.

3. Results

3.1 Results regarding the first question

The codes obtained from the responses of students to the question of “How would you define the concept of science if you had to?” are given in Table 1.

Table 1: Definition of science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Science branches				+			1
Changeable-open to development		+	+	+		+	4
Effort to understand nature-universe	+	+	+	+	+		5
Searching accuracy-fallacy						+	1
Intellectual activities	+						1
Universal				+			1
Based on observation-experience				+			1
Everything related to life	+			+			2
Need-problem		+				+	2
Communication	+						1
Research-investigation process		+	+		+	+	4
Human-made				+			1
Discovery			+				1

Curiosity			+			+	2
Objective				+			1
Problem-solving		+					1
Subjective				+			1
Continuous-perpetual-dynamic		+				+	2
Not possible to exactly define					+		1
Technology	+		+				2

When Table 1 is examined, it is seen that out of the six students, five defined sciences as an effort to understand nature-universe, four as research-investigation process, two as need-problem, one as searching accuracy-fallacy, and one as intellectual activities. Some excerpts are as follows:

....Science examines not only humans, I mean, it is humans' effort to understand the universe, nature, so it starts investigating from the near environment and proceeds to far environments. I mean it examines all living and non-living things, from animals to microorganisms and fungi. ... (P5).

....Development comes to my mind., or discovering things uncovered in the nature, revealing undiscovered things in the nature. Or, finding out about unknown things, investigating and examining them. ... (P3).

...We can call it a branch that examines behaviors in line with the needs of humanity. We can name studies done on any matter that exists in line with the needs as science. ... (P2).

Out of the six respondents, four used expressions such as changeable-open to development, two referred to science as continuous-perpetual-dynamic, and one defined it as objective, and they tried to associate science with scientific knowledge. Related excerpt is as follows:

...Well, in order to call it science, we can say that it must be universal rather than well-accepted. We can say that it should appeal to everyone. Most people are the same, both science and scientific knowledge are universal. .. science is objective. Because it involves events that we can observe, experience, and reach the same conclusion. As I said, boiling of water, the impact of pressure, change in open air pressure, gas pressure in closed cups; all these are universal subjects for the whole world. But, in our childhood, we only knew concepts related to atom such as proton, electron, neutron, with the advancement of science, the concept of quark has emerged. Maybe through years science will also be changeable. ... (P4).

Considering other codes related to the definition of science, it is seen that the participants associated science with concepts such as discovery, curiosity, technology, and communication.

3.2 Results regarding the second research question

The codes obtained from the responses of students to the question of "What are the characteristics of scientific knowledge?" are given in Table 2.

Table 2: Characteristics of scientific knowledge

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Based on mind-reason		+					1
Comprehensible				+			1
Product of investigation-questioning			+				1
Scientific research steps					+	+	2

Advances through accumulation	+	+					2
Open to change-development	+	+	+	+	+	+	6
Experiment-observation	+						1
Verifiable-falsifiable	+		+	+		+	4
Open to criticism		+					1
Universal	+				+	+	3
Well-accepted					+	+	2
Updated		+					1
Imagination						+	1
Within life					+		1
Provable	+		+	+	+		4
Not certain					+		1
Affected by culture						+	1
Objective		+					1
Subjective			+				1
Systematic					+		1

According to Table 2, all students used the expression "open to change-development", four students stated it was verifiable-falsifiable, and four students said it was provable. Sample excerpts are as follows:

...We usually obtain scientific knowledge through experiments and observation in terms of physical sciences. We learned in our undergraduate courses that this knowledge is repeatable and verifiable through experiments. And we also know that this knowledge can change over time. From the perspective of physical sciences, yes, it can be proven, but some additions can also be made to it. I mean, I can say that this is a multiplying situation along with the development of technology and advancement of research. It can be provable. In the proving phase, when the steps followed are repeated, the same results can be obtained. (P1).

... It must be testable. It must mean the same thing to everyone. I mean, scientific knowledge is not A for me B for you. If there is a piece of scientific knowledge, it must be based on proven evidence. In addition, it is always falsifiable. That is, it has an ever-changing feature. It is also developable. (P4).

Table 3: Scientific method

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Research-based			+				1
A gradual process		+					1
Steps that emerge as a result of certain accumulation				+			1
Making knowledge valid-reliable					+		1
Facilitating access to knowledge	+						1
Reinforcing knowledge					+		1
Scientific research steps (problem statement, hypothesis, data collection…)	+	+		+	+		4
Method used to access scientific knowledge	+			+	+		3

Path proving scientific findings	+		+	+	+	+	5
Constant method		+					1
Not well-accepted				+	+		2
Well-accepted	+	+					2
Quantitative-qualitative method				+			1
Scientific research process				+			1
Systematic		+					1

Considering Table 3, it is seen that five out of six students used the feature of being a path proving scientific findings for scientific method, and four mentioned the scientific research steps starting with problem statement and continuing as hypothesis and data collection. In addition, three students used the expression “method to access scientific knowledge”, emphasizing its process feature. Relevant excerpt is as follows:

...In accessing scientific knowledge, we mention that there are certain steps that we should follow. We also say that we should firstly start with a problem statement in order to reach scientific knowledge. Upon forming the problem statement, we establish a hypothesis based on the problem statement. Then we test the hypothesis with experiments and observations. We check whether the hypothesis is supported. Accordingly, we can go back to the hypothesis establishment step, or if it is supported, we move on to supporting it with experiments. We explain it to our students in this way. What I am getting at is that yes, there are certain steps. We reach scientific knowledge by following these steps. (P1).

The excerpt mentioning scientific method do not comply with contemporary NOS understandings. By talking about certain steps, the student expressed that one general method is well-accepted in scientific research process. Moreover, the students listed the advantages brought by scientific method as facilitating access to knowledge, providing validity-reliability, and reinforcing knowledge. The relevant sample excerpt is as follows:

...While providing scientific knowledge, we must give feedback about why these are true. For example, I tell my students that there may be one and a half million species of fungi, but that only 70-75 thousand of these have been identified. Then, they ask how you can predict this number and how are living things categorized. You know, there must be certain criteria for these to be valid. A certain method should be followed. Because they always ask me while I am categorizing living thins why human beings are categorized within animals. I need to come up with certain scientific foundations while transferring this knowledge to my students… (P5).

Table 4: The impact of society on science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Supporting-not supporting viewpoint	+	+			+	+	4
Objective perspective of science				+			1
Being closed to change-development	+		+	+		+	4
Religious thinking	+		+	+		+	4
Thought structure						+	1
Education-knowledge level					+		1
Ethical rules				+			1
Interests and needs		+			+		2
Beliefs						+	1
Culture						+	1

Political decisions					+		1
Socioeconomic level						+	1
Technological literacy level	+	+			+		3
Societal perception				+			1
Investment-economic opportunities	+	+					2

As can be seen in Table 4, the students expressed that society affected science as in contemporary NOS understandings. When asked about how society affects science, four students stated that whether societal viewpoint supports science or not affects science, and that the society being open or closed to scientific studies and religious thoughts of the society affect scientific studies conducted. In a general sense, they expressed that social mentality guides science, and that it has a significant effect on the development of science. The relevant excerpts are as follows:

...There, a scientist was mentioned. I remember his name as Takuyiddin Tusi. He made observations on astronomy. And I also remember that his observations were not welcome by the society, and therefore, his observatory was set on fire. I mean, preventing someone who did studies well beyond his time in terms of astronomy from making observations only because of the society's perspective looked awkward to me then. Even today, society's viewpoint is important... (P1).

... Or society's viewpoint is important of course; their support for scientific studies can change the course of perspectives and scientific research. Of course, the more it is supported by the society, the more it can advance. If it is not supported or there is lack of interest in it, research loses pace, and we cannot make quick progress... (P2).

...Looking back at history, people were afraid to deal with science in times when Christianity had very strict rules, for example. They were dealing with science in secret. They pretended to be committed to their religion, but at the same time, they saw the wrong side of the matter. In such conditions, due to the viewpoint of the society, it was necessary to do scientific studies in secret. So, some perspectives of the society can influence science. This prevents science from advancing. In those times, society did not approve of the studies of scientists with the belief that they might become heretic in a religious sense. But now, science has taken a step forward... (P3).

When Table 4 is examined, it is seen that the students expressed that technological literacy level and education-knowledge level affected science, and that science advanced more rapidly in countries developed in terms of education and technology. In addition, it was stated by the students that investment made in science, economic opportunities, and socioeconomic status also affected science. The relevant excerpts are as follows:

...For example, there is brain drain out of our country now; if a country or government supports science and makes adequate investments in this regard, science develops there; otherwise, brains migrate out of the country to continue their studies abroad. This is what I think on this issue... (P1).

...What makes up viewpoint is culture, belief, and socioeconomic status. For example, it is easier to raise scientists in a society with high level of welfare compared to a structure, culture, or a society where agriculture and human labor are dominant....(P6)

Table 5: The impact of science on society

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Variety of sources of knowledge					+		1
Easier to access knowledge	+						1

Questioning knowledge					+	+	2
Affecting foreign policy				+			1
Being or not being foreign-dependent				+			1
Change in thought structure-open to development			+				1
Improvement in education			+				1
Economic development		+	+				2
Destroying older thoughts						+	1
Meeting needs					+	+	2
Enabling proving						+	1
Mutual interaction		+					1
Generation gap	+						1
Viewpoint					+	+	2
Improvement in health	+	+		+		+	4
Solving problems		+					1
Technological developments	+						1
Advancement-development of society		+	+	+	+		4
Change in attitudes and behaviors					+		1
Easier transportation-communication	+						1

In Table 5, four students emphasized that science enabled society to advance and develop, while 4 students focused on the improvements in health. It was also stated that with the development of science, society's point of view changed, older views were destroyed, and generation gap was created. Sample excerpts are as follows:

… They are interconnected. Science affects society, and society affects science. Scientific changes, developments, and scientific studies will definitely contribute to the development and advancement of society and solutions to its problems. (P2)

...It affects society both in terms of health and economy.... (P2)

… Of course it affects. A whole generation has been differentiated with the effect of science, and we call them as Generation Z. With the advancement of science, technology has developed, and now there are smart phones and Internet connection in every house. It separated one generation from another… (P1).

...It can change and improve a society in terms of its thoughts. It removes the patterns of thought that the society is accustomed to and makes people open to development, more knowledgeable, and more motivated (P3).

In addition, the participants also stated that science provided variety of sources of knowledge and facilitated access to knowledge, but that as there is an information pollution, knowledge should be questioned at the same time. The sample statements in this regard are as follows:

...And there is also this thing, people are trying to receive information from the most accurate source of knowledge due to the pandemic. Because there is too much false information in circulation. How can I get the most correct information….(P5)

...You look at sources of knowledge, they are in the process of shaping. I can summarize it in this way. Science is effective on society in terms of viewpoints, and due to the need for discriminating scientific knowledge, society feels the need to question knowledge. (P5)

It was also expressed that science affected international competition, as can be understood from the codes of being or not being foreign-dependent, affecting foreign policy, and economic development. The relevant excerpts are as follows:

...For example because we do not produce smart phones, we are foreign-dependent and import them. We are affected by foreign exchange rates We are affected by policies. Since we do not produce, we live in a foreign-dependent way… (P4)

New discoveries in science have enabled society to improve. The more advanced a society is, the more economically free it is...(P3)

Table 6: Experiment-observation in science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Accuracy-fallacy of knowledge is tested	+		+	+		+	4
Contributes to science					+		1
Enables access to scientific data	+						1
Can be used together		+					1
Experiment aims at proving		+					1
Experiment yields a generalizable result		+					1
Experiment reveals phenomena				+			1
Science is not possible without experiment and observation			+	+			2
Provides permanent learning					+		1
Provides validity-reliability	+						1
Provides universality	+						1
Observation in in-depth analysis		+		+			2
Observation in qualitative studies, experiment in quantitative studies		+		+			2
No experiment without observation, but observation with experiment		+	+				2
Provides proof-justifiability	+	+	+		+	+	5
Repeatability		+	+			+	3
Essential but not inevitable						+	1

In Table 6, it is seen that the students generally expressed that experiment and observation provided provability for scientific knowledge, that they were used in testing accuracy and fallacy of knowledge, and that they ensured repeatability. Sample excerpts in this regard are as follows:

… Scientific studies must be proven and the result must be repeatable. Hence, the role of experiment and observation is very important… (P2)

… Sir, what we call science is actually based on experiment and observation. Because they can verify or falsify what individuals can see and test… (P4)

It is seen in the table that the students emphasized the importance of experiment and observation with statements such as “contributing to science, enabling access to scientific knowledge, ensuring permanent learning, and providing validity and reliability and universality.”

...Looking from here, we see that most of the data obtained through scientific methods are obtained through experiment and observation. Therefore, I think experiment and observation are important. In fact, they test the accuracy of our knowledge. I mean, if I get a result, and another person gets another result, I cannot prove its accuracy. Then, I get stuck in the hypothesis step. But, if I want to ensure universality and reliability of knowledge, I must definitely prove the accuracy of the results… (P1)

In addition, it is seen that the students evaluated experiment and observation comparatively by stating codes such as “experiment aims at proving, experiment is preferred in order to put forth a generalizable result, experiment reveals phenomena, observation is used in in-depth analysis, observation is used in qualitative studies, experiment is used in quantitative studies, experiment without observation is not possible, but observation without experiment is possible.” The relevant excerpt is as follows:

...In what kinds of studies do we use observation? Mostly in qualitative research, wo make observations and by reaching a result, we try to solve a problem or put forward something new. Mostly, when we want to do in-depth studies, we use observation method a lot. Then, when do we use experiment? In experiments, when we want to prove something and to reveal a definitive result or a generalizable result, we experiment and by reaching the same result at every trial, we produce an outcome. In other words, what we call observation is at the beginning of an experiment. But, something can be observed first, and then it can be researched. I mean, even when you are going to do something experimental, you still need observation in order to create a problem statement. But, when we want to do more in-depth studies, or when we want to reveal a situation, say, on a subject, or do some research on that subject, we use observation more. (P2).

Table 7: Imagination and creativity in science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Trigger research			+				1
A feature that a scientist must have		+			+		2
Science is born from imagination				+			1
Starting point in science			+	+		+	3
Advancement of science	+				+		2
Supportive in producing solutions-creating a product	+			+		+	3
Experiment is imagined before observation			+				1
Different perspective				+			1

Are in human nature			+				1
Effective in ensuring permanent learning					+		1
Necessary for introducing the problem	+						1
Are based on curiosity				+		+	2
Productivity-synthesis				+	+		2

All students expressed that scientists used imagination and creativity in scientific process, and they provided responses that overlap with contemporary NOS understandings. The codes extracted from the responses are given in Table 7. As can be understood from the codes, some students stated that imagination and creativity are necessary for introducing the problem, that science was born from creativity, and that they triggered research, emphasizing that imagination and creativity were used at the start of scientific process. The sample excerpts in this regard are as follows:

.... Consequently, most scientists imagine things before they experiment and observe. Because imagination is in human nature. Even now as I am talking, I am imagining the pictures in the books we have read or the experiments that scientists did, they come to life in my mind. Imagination is very important. For example, take Einstein, he could not prove his theories, but he discovered them in his imagination, and later they were proven… (P3).

… Therefore, I certainly believe that science is intertwined with creativity. I mean, science is born from creativity, to tell the truth. What we call creativity are new things. Something thought differently. This is what science does. Looking at the existing problem in a way that was not thought before, looking with a new perspective; science is in fact the effort to produce a new solution; that is why it is based on creativity… (P4).

Some students expressed that imagination and creativity were supportive in producing solutions and creating products, and that they were necessary for productivity and synthesis. The relevant sample excerpt is as follows:

…Well, let me give you a very simple example. Imagine a farmer. Let's say the farmer has difficulty with some fruit he is trying to pick from a tree and thinks how he can solve the problem. Then, he should use his imagination so that something can be formed in his mind. He must be creative in order to find a solution to this problem. I can give you many similar examples…(P6).

Regarding other codes obtained from the interviews, it is seen that the students expressed that imagination and creativity were among the characteristics of a scientist, and that they were effective in the advancement of science. The relevant excerpt is as follows:

…This is because if a person's imagination has not developed, he can progress within certain standard patterns. But, imagination, creativity, problem-solving skill, creative entrepreneurship skill which we call innovation, presentation skill, all of these must be present in a researcher., I think… You know, we learn something, but after this process, if imagination and creativity step in, we can form more novel and more comprehensive knowledge. This both ensures faster development and increases the variety of the data and knowledge, as I mentioned in our previous interview… (P5).

Table 8: Social and cultural values in science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
Guide research	+	+				+	3
Perspective		+				+	2
Pressurizing and suppressing			+				1
Affect starting point-purpose						+	1

Investment in science	+						1
Supportive or unsupportive		+					1
Religious belief			+		+		2
Ethical values		+					1
Understanding of freedom						+	1
Political view			+	+			2
Social environment		+					1
Social structure			+			+	2
Socioeconomic level			+	+	+		3
Historical ages						+	1
Technological development	+						1
Interests and needs of society		+		+	+		3

In Table 8, the codes regarding social and cultural values are presented. It can be stated that the students adopted contemporary understandings of science and expressed that science was affected by social and cultural values. The students stated that depending on the social and cultural values of the society, interest and needs could change, that the society's perspective could guide research, and that the social structure, religious beliefs, and ethical values of the society might affect scientists and therefore science. The relevant excerpt is presented as follows:

… Yes, it is affected by social and cultural values. Whatever the social needs of humans are, I keep coming to the same point; As I believe the starting point of scientific studies is needs, social needs or individuals' status in social life are effective as well. I mean, studies conducted with the perspective of a certain society can also change. For example, no studies defying the values of the society can be done, or in terms of ethical values, a study conducted disregarding these values and considered inappropriate cannot be conducted. In such situations, it may be difficult. Maybe, you would not feel the need for conducting a study. I mean perspective and cultural conditions guide studies conducted. Yes, and this inevitably changes the course of scientific studies… (P2).

Table 9: Theory and law in science

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f
There is hierarchy	+	+			+		3
There is no hierarchy			+	+		+	3
Law superior-theory inferior stage	+						1
Law is more certain	+	+		+	+		4
Law can be proven with experiment			+	+	+		3
Law is recognized by all		+				+	2
Law and theory have different perspectives			+				1
Laws cover theories					+		1
It is difficult to change laws- theories change easily	+				+		2
Law-theory can change			+	+		+	3
Theory is an effort to explain a situation				+			1

Theory is rather related with thoughts			+				1
Theory is not recognized by all		+				+	2
Theory cannot be proven		+	+	+		+	4
Theory can turn into a law		+					1
Theory is not applied		+					1
Theories are newer					+		1
Theories do not turn into laws				+		+	2

Considering Table 9, it is seen that half of the participants adopted modern nature of science understanding and expressed there was no hierarchy between theory and law, while the other half stated that there is a hierarchy between the two, thus showing that they did not adopt modern understanding of science. It was also observed that the participants had difficulty in defining theory and law during the interviews.

Th codes related to contemporary scientific understanding were "law and theory have different perspectives, laws and theories can change, theory is an effort to explain a situation, theory is rather related with thoughts, and theories cannot turn into laws." The relevant excerpts are as follows:

… No, there isn't. A theory is mostly in a scientific dimension, I mean, it is in the intellectual dimension; it is not definite and false, but we cannot prove it with experiment. But we can prove or show a law with experiment. As a theory, like I said, mass gravity theory is not a law for example. We accept it, but it has nothing to do with a law. Laws are based on experiments, and we can show them. An example for a law is the law of gravity. We van see it by dropping an object, or we can see it in the movements of an object by creating an environment without gravity. Or we can create an environment without air and we can prove the law by dropping objects with different masses and observing them fall in the same way. But, a theory is in the intellectual dimension, and it will take more time to discover and prove it. They have different perspectives, and they have scientific knowledge and changing natures. The theories and laws we accept today can change in future. They are not definite. (P3).

… I know that there is no hierarchy between these two. That is what I remember. In master's courses, in undergraduate courses, and in secondary school coursebooks, I saw many texts saying that the two are different and cannot turn into one another, and I searched it. As far as I can remember, law is proven from different aspects and recognized. Theory is also recognized, but it cannot be directly proven. But, both laws and theories can change. To give an example to theory, take the Big Bang theory; nobody can travel back to the formation of the universe or do extra experiments related to this. Yes, you cannot say it occurred, but you are making inferences from observations regarding its occurrence. (P6).

The codes related to the traditional understanding of science were "law is superior, theory is inferior, law is more certain, laws cover theories, theories can turn into laws, theories cannot be proven." The relevant excerpt is as follows.

… I actually remember from my university years that there is a hierarchy. Theories are generally tested and approved. I mean, yes, it is also valid as scientific knowledge, but laws, how should I put it, laws are more certain, as I remember. I mean, I can say it is one more step superior. I want to say that laws involve more definite information from a scientific perspective… (P1)..

Table 10: Theory-laden NOS (subjectivity in science)

	Participants						
Codes	P1	P2	P3	P4	P5	P6	f

Science is a product of humans			+	+	+		3
Science is subjective			+			+	2
Scientific knowledge can change-not certain				+			1
It is affected by religious beliefs						+	1
It is universal- objective as it is recognized by all					+		1
Experiment can be proven with observation in science	+						1
Observation is the same, inferences are different			+				1
Personal life-experiences affect the process					+		1
The result is universal and well-accepted		+					1
Experiment cannot be proven with observation in social field and philosophy	+						1
It is affected by social and cultural values						+	1
Knowledge is not certain in social-philosophy field	+						1
It is subjective in social-philosophy field, objective in science field	+						1
Process is subjective, and result is objective		+					1

Considering Table 10, there were differences of students' understandings regarding the theory-laden nature of NOS. Some students stated "science is a product of humans, it is affected by religious beliefs, personal lives, and social and cultural values, observations are the same, but inferences are different," thus emphasizing its subjectivity. The relevant excerpts are as follows:

… As I have always said, I think science is subjective, because as I said, when humans are subjective, what they discover becomes subjective as well. Even if we look at the same thing, we see very different things. The meaning, thought, and expression created in us are different. For example, laws, now everyone recognizes them. Yes, we say there is law of gravity, there is gravity, and it pulls things toward the earth. But still, it may mean different things to people; For some, it means a formula and definition, gravity concept creates a different picture in others. It is the speed of falling of an object. (P3)

… I think scientific knowledge is subjective. It is subjective because it is affected by social and cultural values, religious beliefs, and social structure. (P6).

With statements such as "experiments cannot be proven with observations in the social-philosophy field, knowledge is not definite in social-philosophy field, it is subjective in social-philosophy field, but objective in science field, process is subjective, but result is objective," some students expressed that science includes both subjectivity and objectivity. The relevant excerpt is as follows:

… As I said in response to one of the questions, it is necessary to distinguish scientific knowledge in terms of physical sciences and social sciences. Here, social sciences and philosophy are also sciences, and there is scientific knowledge in those fields. But, I think while scientific knowledge is more subjective in social sciences, it is more objective in physical sciences. One of the main reasons for this is that physical sciences depend on experiments, observations, and proof. If we are teaching scientific knowledge in physical sciences in a lesson, we teach them as proven knowledge. But as I said, I am talking from the perspective of physical sciences. In social sciences, especially in a science branch like philosophy, it would not be correct to express it in this way. This is because in these fields, there are no experiments and observations in order to reach definite knowledge. If we give an example from a social studies course, there are some history subjects here, and for these subjects' certain dates are given, but when a dig is performed or a study is conducted, a new discovery is made, and the knowledge changes. In terms of physical sciences, yes, as a result of experiments and observations, many new things are added on each other and can change, but in social sciences, these changes are much more, and these changes are not definite. Or think about philosophy course. It is totally based on thoughts, and thoughts are subjective. So, philosophy course is a course in which personal opinions of people are more intense, and as much as I can remember from my high school years, in this course many people's ideas are mentioned, and these ideas are not related to each other. And we accept all this knowledge as scientific knowledge. We do not accept any of them as false. When looked from this perspective, the existence of various ideas and presenting an assortment of ideas without expressing them as right or wrong show subjectivity rather than objectivity. (P1).

On the other hand, others stated that science was objective as it was universal and recognized by all, and that it was objective as the result was universal and well-accepted. The relevant excerpt is as follows:

… Recognition of scientific knowledge by everyone and thus its gaining a universal aspect make it objective (P5).

4. Discussion

4.1 Discussion on the first research question

It has been determined that students use expressions such as research and inquiry process, understanding nature and the universe, associating science and scientific knowledge, open to change and development, and dynamic continuous while describing science. Therefore, it can be said that the students consider science as an activity open to change and development, which includes understanding nature, especially through the research-inquiry process. There are similar studies in which expressions such as revealing the unknowns of the world and the universe, understanding the world or science emerges in line with the needs for the definition of science (Duruk et al. 2019). However, scientists do their research freely, without practical expectation, for the purpose of satisfying their own curiosities and questioning nature, rather than meeting human needs (Sagan, 2011). When the definitions were examined in depth, it was seen that the students mostly tried to explain their mixed and informed NOS understandings with the assumptions of the positivist paradigm. In addition, it was noted that while they were revealing their understanding of science, they sometimes described science with contradictory words with opposite meanings (Abd-El-Khalick, 2005). This situation increases the possibility that the students, who are potential scientists of the future, will conduct research studies on positivist assumptions and cause many misconceptions about science in their students as science teachers (Morrison et al., 2009). It is important for teachers to have informed understandings of science because these understandings have an important role in students' decision-making processes based on scientific knowledge and in developing contemporary views on science (Duruk et al. 2019; Khishfe, 2012).

4.2 Discussion on the second research question

The students emphasized the features such as being open to change, being verifiable/falsifiable, and being provable, which are thought to be suitable for the contemporary science paradigm, while half of them discussed the feature of being universal from a positivist paradigm (Table 2). This situation shows that prominent concepts may indicate a mixture of both paradigms.

It has been observed that scientific research is a demonstrative way and it is more frequently mentioned that a certain sequence is followed along this path (Table 3). It can be said that these understandings evoke the myth of scientific method. The scientific method myth is a misconception based on positivist assumptions that science is a monotonous activity and should be carried out in a certain order (Urhahne et al. 2011; Turgut, 2009). This situation increases the possibility of teachers conducting science lessons to transfer this myth to their students. The spread of this myth may cumulatively lead to the perception of science as an objective and standard procedure rather than an activity based on imagination and creativity (Lederman et al. 2002). Therefore, the emphasis that experiments are one of the ways of collecting evidence rather than being a final proof should be emphasized in all teaching settings, especially in case of the possibility of teachers to convey these misconceptions during the conduct of experiments, which are frequently included in science curricula. In the current study, it was seen that the students saw the creative NOS as the initial stage of the research and they often thought of creativity as creating a product. Thinking product-oriented rather than process-oriented and positioning imagination and creativity only in the beginning stage of science is typical positivist approach. Therefore, it can be inferred that the students have an understanding that starts from the myth of the scientific method and uses it in a way that limits the scope of creative NOS. When we look at the literature, it is seen that there are studies on NOS conducted with teachers, in which teachers who participated in the studies stated that imagination and creativity in science are used at every stage of research (Yalvac & Crawford, 2002; Abd-El-Khalick & Akerson, 2004). According to the findings of some studies, teachers state that imagination and creativity are more important in the preparation phase of the research, the experimental phase and the data collection steps (Abd-El-Khalick & Akerson, 2004). Both cases differ from the present study.

All of the students stated that society affects science. They stated that many factors such as the religious thoughts of the society, ethical values, technological literacy levels, education levels and being closed or open to development and change affect science. In this case, it can be said that the students are closer to the contemporary understanding (Khishfe, 2012). It is seen that the students adopted the contemporary view in the dimension of societal NOS and stated that science has a positive effect on the society in general. It is mentioned that the progress in science provides the development of societies, being open to development, change and breaking old-fashioned patterns, and it is mentioned that it provides convenience in many areas such as access to information, communication-communication in the field of health, since it serves the development of societies economically and politically. However, the students did not state a any view that science would have a negative impact on society. When the literature is examined, it is seen that, unlike the current study, Özbudak Kılıclı & Polat (2015) in his study with pre-service science teachers mentioned that the studies-experiments made by scientists can produce both positive and negative results. Considering that there is no limitless optimism about the benefits of science (Sagan, 2011), it is noteworthy that the students did not state that science can produce negative results.

When asked about the theory-law component, half of the students stated that there was a hierarchy, while the other half stated that there was no hierarchy. While most of the students stated that the theory could not be proven, some students stated that there is a hierarchical relationship between theory and law, and that theories can turn into laws if proven. This situation reveals that the they have misconceptions. The present findings are similar to previous studies (Akerson et al. 2006; Liu & Lederman, 2007; Parker et al. 2008). When asked about the theory-laden NOS, the students repeated their responses to other characteristics – such as science is a product of human beings, influenced by religious beliefs. In this situation, it is understood that the students are not aware of what scientists do in their studies in line with a theory, that the theory comes first. Some of the students stated that science is subjective, arguing that it is a human product, and that it is affected by religious beliefs, personal lives, social and cultural values. In contrast, some participants expressed that it is objective because it is supported by experiments and observations in the field of science and is universally accepted by everyone. Students expressing both situations show that the objectivity of science stems from examining objective facts rather than subjective facts, and it is not understood that science should be as objective as possible, as well as being affected by scientists' religious thoughts, worldviews and so on. There are studies in the literature showing that both teachers and students have similar misconceptions (Yalvac & Crawford, 2002).

5. Conclusion

Students has mixed and informed NOS understandings in terms of the characteristics of scientific knowledge and the socio-cultural structure of science. However, they have inappropriate understandings regarding scientific method, law-theory and creative, theory-laden NOS. It has been concluded that they lack informed NOS understandings and explain these understandings with positivist assumptions. In addition, it has been determined that they use the assumptions of the interpretive paradigm more when expressing their understanding of science compared to other components of NOS. Moreover, it was determined that the students believed in some myths about NOS and had misconceptions about law, theory, and the objective and subjective NOS. In order to develop NOS understandings of students who have the potential to become future scientists, it may be suggested to improve NOS in science curriculum. Possible reasons for the different levels of NOS understandings (informed-mixed-inappropriate) can be explored by additional research practice to response the question of why some NOS components show more resistance to change.

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