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STEM-Based NOS Teaching on 7th Grade Students' NOS Views

Günkut MESCİ[1]

Giresun University

Eda ERDAŞ-KARTAL[2]

Kastamonu University

Abstract

The aim of the study is to improve students' nature of science understandings while integrating nature of science aspects into appropriate science-technology-engineering-mathematics (STEM) activities. In this study, four STEM-based contextualized nature of science activities are developed during the 4 weeks study. The sample of this study consists of eighteen 7th grade students. The data are collected the views of nature of science questionnaires (VNOS-D), follow-up interviews, and classroom observations. All data are analyzed holistically to create a profile of students' views for the targeted aspects of nature of science with using content analysis. The analysis showed that 7th grade students have generally naive views of the targeted nature of science aspects before participating in the 4-week study. After STEM-based nature of science teaching, all students improved their views of nature of science. STEM-based explicit-reflective nature of science teaching may be an alternative approach to improve students' nature of science views, and it is recommended to use this approach in the future studies.

Keywords: Science Education, Nature of Science, Scientific Literacy, STEM-Based Teaching

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[1]Dr., Education Faculty, Giresun University, Giresun, Turkey, ORCID: 0000-0003-0319-5993, Email: gunkutmesci@gmail.com

[2] Assist. Prof. Dr., Education Faculty, Kastamonu University, Kastamonu, Turkey, ORCID: 0000-0002-1568-827X **Correspondence**: erdaseda@gmail.com

Introduction

Nature of science (NOS) has been considered a critical component of scientific literacy in reform documents all around the world (e.g., AAAS, 1993; MoNE, 2013; 2018; NGSS Lead States, 2013). Although there is no single definition of NOS (Lederman and Lederman, 2012), NOS has been defined as the epistemology of science, the role of scientists in a scientific research, and the improvement of scientific knowledge (Lederman, 2007). Clough (2006) defined NOS as understanding of how scientific knowledge is produced, what science is, the basic elements of science, the interaction between science and society, and the role of the scientists.

Recent studies have recommended that NOS should be a part of all science courses (Mesci, 2016; Lederman and Lederman, 2014; Olson, 2018), and emphasized the importance of NOS teaching for all students (Akerson, Elcan-Kaynak and Avsar-Erumit, 2019; Murphy, Smith and Broderick, 2019). However, teaching of NOS is quite difficult. There are mainly two approaches (implicit and explicit/reflective) that have been used for teaching NOS (Abd-El-Khalick and Lederman, 2000a; Lederman, 2007; Lederman and Lederman, 2014). In the implicit approach, it is assumed that students can learn NOS aspects by themselves during the activities or laboratory applications without emphasis (Schwartz, Lederman and Crawford, 2004). On the other hand, in the explicit/reflective approach, NOS aspects are explicitly and reflectively associated with the scientific practices (Khishfe and Abd-El-Khalick, 2002). Explicit/reflective NOS teaching is not just about directly telling the students the NOS aspects that are intended to be taught. It involves explicitly linking the activity with the NOS objectives to be taught, making connections with students' previous experiences, reflecting their learning on NOS aspects, and assessing their understandings of NOS aspects. Research reveals that the explicit/reflective approach is more effective than the implicit approach in teaching NOS aspects (Khishfe and Abd-El-Khalick, 2002; Lederman and Stefanich, 2006; Schwartz et al., 2004). There are some different ways for conducting explicit/reflective NOS teaching (i.e., argumentation-based, inquiry-based, PCK-based etc.) (Mesci, 2020; Cofre et al., 2019; McDonald and McRobbie, 2012). The explicit/reflective approach in NOS teaching can be used through activities and discussions embedded in science content (contextualized) or not embedded in science content (decontextualized) (Akerson et al., 2019).

Although the importance of teaching NOS and improving students' NOS views have been reported more than 50 years, it has been demonstrated that students' NOS views are still limited and insufficient (Cofre et al. 2019; Karakaş, 2017; Lederman and Lederman, 2014; Park, Nielsen and Woodruff, 2014). Research reveals that NOS teaching still does not provide place in many science classes, and even where it is given, it is often attempted to be taught ineffectively through an implicit approach or implicit examples from history of science (Capps and Crawford, 2013; Kruse, Kent-Schneider, Zacharski, and Rockefeller, 2019). Even if explicit/reflective instruction has been performed, it has been shown that it still does not have complete success, or has limited success in some cases (Mesci and Schwartz, 2017; Cofre et al., 2019). Thus, it has been recommended to explore how NOS teaching aligns with and supports other inquiry-based science teaching practices (e.g., Bell, Mulvey, and Maeng, 2016; Clough, 2018), and to conduct empirical research of alternative NOS teaching models in order to improve NOS views of students at all ages (Lederman and Lederman, 2014).

Theoretical Framework

Science, Technology, Engineering, and Mathematics (STEM) educational approach theoretically leads to this study. STEM is aimed at high-level skills such as science literacy, technology literacy, communication, flexibility, adaptability, creativity, critical thinking, collaborative work, and problem-solving skills that are called 21st century science skills. STEM has met with great interest and support in many countries along with the United States (Akerson et al., 2018; Yager and Brunkhorst, 2014). This intense interest in STEM is also reflected in academic studies (Breiner, Harkness, Johnson and Koehler, 2012; Derin, Aydin and Kirkic, 2017). As a result of the studies based on STEM approach, it is revealed that students found STEM applications to be fun and motivating (Canbazoğlu-Bilici and Ünal, 2015; Gökbayrak and Karışan, 2017), these applications developed students' attitudes towards science (Keçeci, Alan and Zengin, 2017; Ricks, 2006; Tseng, Chang, Lou, and Chen, 2013), increased students' participation in scientific inquiry activities and course (Bransford, Brown, and Cocking, 2000), and developed students' scientific process skills (Yamak, Bulut and Dündar, 2014). Thus, the NOS teaching in the current study has been designed with STEM-based NOS approach. This approach requires that the targeted NOS aspects needs to be integrated into appropriate STEM activities and emphasized the relationship between NOS aspects and the STEM disciplines explicitly/reflectively. The STEM-based NOS teaching is based on the "NOS Teaching Cycle" model (Akerson et al., 2010), which has been recommended for teaching NOS to young children (Akerson et al., 2010). The NOS Teaching Cycle consists of three main activities (introductory, inquiry, and debrief activities). During the teaching cycle model, the students should be first introduced to the concepts of NOS by associating them with their prior knowledge, and in the next stage, the students should make inquiries to associate their research with NOS, and in the final stage, the indented NOS aspects through debrief activities should be given in an explicit/reflective manner (Akerson et al., 2010). The relationship between NOS and all the disciplines of STEM has been expressed as understanding the ways and the philosophy underlying the processes of doing science (Akerson et al., 2018). It is great importance to understand the ways of scientists that they use mathematical theorems to do science by integrating technology into engineering applications for raising scientifically literate individuals. In order to understand this potential impact, it is valuable to examine the effectiveness of STEM-based approach for learning and teaching of NOS.

Although there is still ongoing debate about listing of NOS (Abd-El-Khalick and Lederman, 2000b; Allchin, 2011; Irzik and Nola, 2011; Erduran and Dagher, 2014), science educators have been a consensus on some aspects of NOS (Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). Considering the grade level of the students who involved in this study, it was focused on some targeted NOS aspects, which are; (a) scientific knowledge is tentative; (b) scientific knowledge is based on observations and inferences; (c) scientific knowledge is subjective and theory-laden; (d) scientific knowledge is empirical based; and (e) creativity and imagination plays an important role of all stages of producing scientific knowledge (Lederman, 2007).

Purpose of the Study

The aim of this study is certainly not to make students understand all STEM disciplines or to train students who are an engineer, a mathematician, or students who use technology wonderfully. In this study, it was aimed to investigate how the STEM-based NOS teaching effect the 7th grades students' NOS views. In this regard, the research questions as follow:

1. How do 7th grade students' NOS views change after the intervention of STEM-based NOS teaching?
2. What are the most influencing parts of STEM-based NOS teaching on students' NOS views?

Method

The development of 7th grade middle school students' NOS views was qualitatively examined during a 4-week STEM-based NOS intervention. Each participant's views of NOS and changes were investigated throughout open-ended questionnaire and follow-up interviews as a multiple comparative case study (Creswell, 2007). Students' views on the effectiveness of STEM-based NOS teaching were examined qualitatively through interviews.

Participants

The sample of this study consists of eighteen (10 male, 8 female) 7th grade students (age: 12), who are located in an Anatolian city in Turkey. Turkish science education system is based on inquiry-based learning, so students are generally taught science with inquiry (MoNE, 2018). However, the students have not received any specific study or training about STEM or NOS. The students generally have an average success in science. After obtaining the necessary permissions from the school district, the students voluntarily participated in the study with the permission of their science teacher.

Context of the Study

In this study, four STEM-based contextualized NOS activities were developed and implemented by the researchers to increase students' NOS views during the 4 weeks intervention (once a week for 4 hours each). Each activity is summarized below and one of them is detailed in the appendix. In general, STEM-based contextualized NOS activities consist of three main stages: "introductory", "inquiry", and "reflection" (An example of how each stage was implemented in STEM-based NOS activities is provided in Appendix). The following guidelines for each stage were implemented to each activity. In the introductory stage, it was firstly aimed to reveal students' prior knowledge about the science subject and NOS aspects. Then, the students' interest towards science was attracted by asking provocative questions for making them ready to inquiry activities. In the inquiry stage, the students were engaged in the activity with using "activity papers" (see Appendix for an example). In line with the instructions in the activity paper, the students designed and made their own models through. The activity papers enabled students to grasp the relationship between science, engineering, technology, and mathematics by making them feel like scientists, engineers, or inventors. It also helped students learn in a meaningful way the targeted NOS aspect by engaging the activities. The level of inquiry in these activities was chosen as guided inquiry, where the research question was given by the teacher, but the method and results were determined and put forward by the student (Bell, Smetana, and Binns, 2005). In the last stage, reflection activities were carried out in order to reinforce the students' learning and understand how much they understood the NOS and its relation to STEM disciplines throughout formative assessment and reflection papers in each day (see Appendix for an example). The formative assessment papers were used to evaluate the students' understanding of science content, NOS, and STEM relation. In the formative assessment, the students' learning and misunderstandings were determined and then in the next lesson, they were provided feedback during the process, which helped also researchers to make the necessary adaptations for the success of teaching on time (Guskey, 2000). In the reflection essays, students were asked to write at least two paragraphs, which include a summary of what is done in the lesson and the relationship between STEM disciplines and NOS aspects.

Activity 1: Make Your Own Telescope

In this activity, the students were expected to explain the structure of the telescope, to establish a relationship between technology and space research, and to design a simple telescope model. In addition, the students were expected to understand that scientific knowledge can change through new data and developing technology, to realize the role of imagination and creativity in science, to understand the subjectivity, and to figure out that science is based on observations and inferences. In this activity, the students like a scientist and engineer, drew their own telescope designs, and made them real with appropriate mathematical measurements on the lens of telescope (see Appendix for details of this activity).

Activity 2: Young Histologists

In this activity, students were expected to compare the tasks of animal and plant cells and to discuss the development of cell structure from past to present with the development of technology. In this context, the students were expected to realize that scientific knowledge is tentative in the light of new data, to understand the subjective structure of scientific knowledge, to realize that they use their imagination and creativity when designing cell models, and to understand that observations and inferences plays an important role of producing scientific knowledge. The development of cell theory was broken up into pieces and given to students in envelopes in stages, and the students renewed and changed their drawings of the cell model they would design each time, limited to the information they were provided. After, the students examined and compared animal and plant cells in the microscope. Then, they designed and implemented cell models that would simply represent the cell structure similar to those observed.

Activity 3: My Electric Circuit

In this lesson, the students were expected to observe the series and parallel electrical circuit, and to identify the electrical current, and explain that electrical energy is transferred to the circuits by current. In addition, by designing an authentic lighting tool, they were expected to understand the subjective structure of scientific knowledge, to realize the development of electricity over the years, and so that scientific knowledge is tentative, and to explain the difference between observations and inferences with using a computer-based simulation. In this activity, the students designed original lightening devices and tested in the laboratory and in the computers via simulations by designing an electrical circuit in the light of their own existing knowledge and their creativity, like an engineer. By testing the circuits designed in the laboratory and in simulation, they realized the effect of technology on scientific developments and will be able to comprehend the empirical structure of science. In this lesson, the contribution of different scientists who are not only scientist but also engineers/inventors (e.g. B. Franklin, N. Tesla, and T. Edison) to electricity was explicitly discussed. This lesson was specifically developed to show the impact of students' creativity, imagination, authentic thinking, experiences, and theoretical assumptions on the lightening devices that they designed, and concluded that scientific knowledge, thus technology and engineering is influenced by scientists' creativity, previous experiences, and theoretical assumptions. Also, throughout this activity, it was aimed that students recognized the importance of and differences between observation and inference by detecting conductive and insulating materials in the electrical circuit when testing their own circuits in simulation.

Activity 4: Conservation of Energy

In this lesson, the students were expected to draw the conclusion that energy is conserved by transforming kinetic and potential energy types into each other. In addition, by designing different models, the students were expected to understand scientific knowledge is subjective and based on observations and inferences. Also, they were expected to figure out the importance of creativity, and to understand the experimental structure of scientific knowledge. In this activity, the students realized how much the technological tools made by conservation and transformation of energy have benefited mankind by designing a model in the light of existing knowledge like engineers. In this lesson, students watched some videos about different skate parks. They drew pictures and then develop their own skate parks based on their observations. Then they tested these skate parks in a computer simulation. During the simulation, they changed the measurements of and revise their skate parks. Then, they shared their ideas to other students. In particular, they recognized that it has been developed to produce new technologies such as cars, airplanes, solar panels throughout the mathematical calculations and efficient energy transformations become more accurate. In this way, technology has been changed and developed, just as scientific knowledge may change in the light of new data and evidence. They also discussed how the technologies are produced especially the impact of the creativity of scientists and their authentic ideas, past experiences and theoretical assumptions.

Data Collection and Data Sources

The data were collected throughout pre and post format of the views of nature of science questionnaires (VNOS-D) (Lederman and Khishfe, 2002), semi-structured interviews (Lederman, Abd-El-Khalick, Bell and Schwartz, 2002), in-class audio recordings, and classroom observations. The original VNOS-D questionnaire consists of 10 questions, but it was implemented as 7 questions as used in Özer, Doğan, Yalaki and Cakmakci (2019) when considering the age of the participants. Validation of the questions has been provided by the method of re-translation. In this process, a language specialist translated the questions selected from the questionnaire from English into Turkish, and another language specialist translated it back into English. Two English versions of questionnaires were compared side by side and no meaning loss was observed in the questions.

The semi-structured interviews were conducted to make students clear about their responses, give examples, or explain what they meant on the questionnaire. The interview protocol, which was recommended by Lederman, et al. (2002) for the VNOS questionnaire, was used. Each interview took about 20 minutes. In addition to survey and interview, each STEM based NOS teaching session was audio recorded. All interviews and classroom audio recordings were transcribed for further analysis.

Data Analysis

All responses in questionnaire and interview transcripts were considered holistically to create a profile of the participants' understanding along the targeted aspects of NOS. A profile was developed for each student, representing their views, from naive "-" to mixed "(+)" to increased "+, ++, +++" informed levels. The NOS continuum scale allows researchers to understand students' views and changes in a spectrum (Schwartz, 2007). When students have opposite understandings to the currently accepted NOS views in the literature, they are coded in the "-" range of views. If the students have an inconsistency and conflict in their NOS views, they are coded in the "(+)" range of view. If the students gave answers stating that they agree with the accepted NOS views, they are coded in the "+" range of view. If they also explain their responds with an authentic expression with their own words, they are coded in the "++" range of view. If they support their authentic expressions with appropriate examples, they are coded in the "+++" range of view (Lederman et al., 2002). NOS continuity scale represents a series of views within a sample display (Mesci, 2016). The remaining data including classroom audio records' transcriptions were analyzed by using content analysis for supporting the data from the questionnaires and interviews. The content analysis consists of coding data, creating categories and themes from codes, and visualizing data (McMillan and Schumacher, 2010). 20% of the data were reviewed by researchers and two independent experts. After completing their analysis, the researchers and experts discussed the results until at least 90% agreement was reached. Then the researchers analyzed the rest of the data based on the initial analyzes obtained.

Results

According to the analyses, 7^{th} grade students had generally naive views of the targeted NOS aspects before participating to the study. After STEM-based NOS teaching was performed, an improvement was observed in their NOS views. Almost all students have improved their NOS views, and no student left in the naive range (Figure 1).

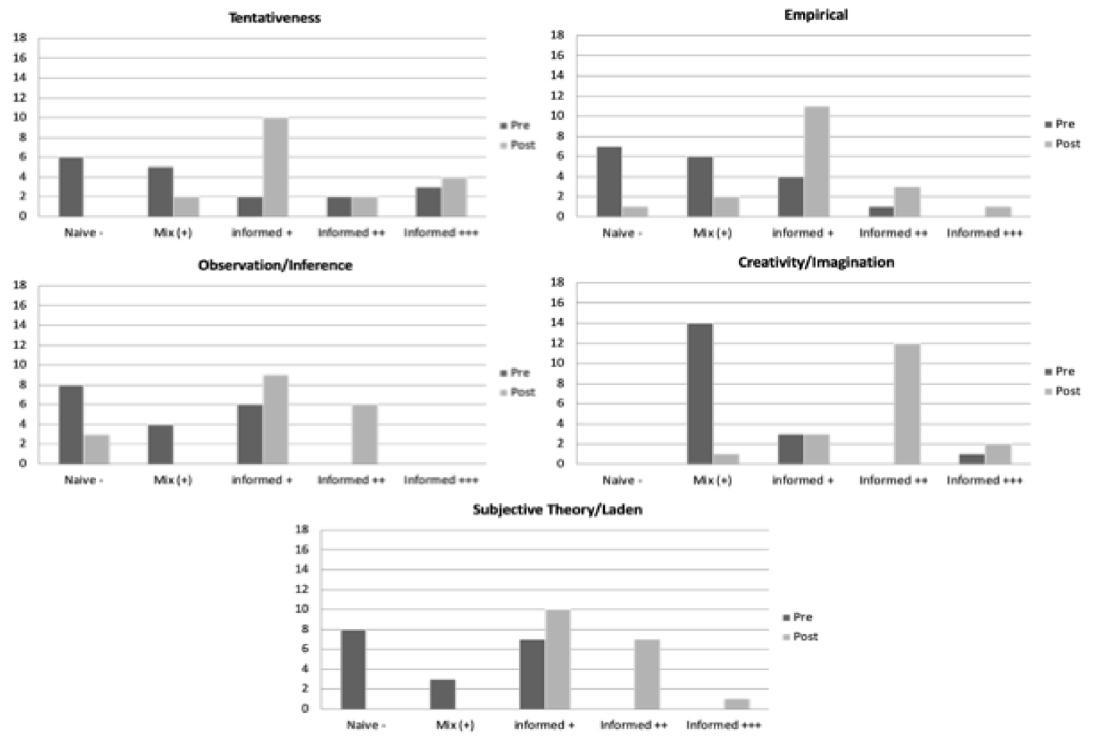

Figure 1. The Changes of Students' Views in Relation to NOS Aspects

Table 1 shows the improvement of the views of each student for each NOS aspect throughout the study, and Table 2 represents the students' views of targeted NOS aspects before and after the intervention. The development and change of students NOS views, and impact of STEM-based NOS teaching in each NOS aspect are detailed below.

Table 1. Alignments of 7th Grade Students' Views of NOS with Current Reforms

	Tentativeness		Empirical Based		Observation/ Inferences		Creativity/ Imagination		Subjectivity	
Participants	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
S1	-	+++	-	+	-	-	+	++	(+)	++
S2	+++	+++	+	+	-	+	(+)	(+)	(+)	+
S3	+++	+++	+	++	+	++	(+)	+++	+	++
S4	++	++	-	++	+	++	(+)	++	-	++
S5	+++	+++	++	+++	+	++	+++	+++	+	++
S6	++	++	(+)	+	(+)	++	(+)	++	+	+
S7	(+)	(+)	(+)	++	(+)	++	(+)	++	+	++
S8	(+)	+	-	-	-	-	(+)	+	-	+
S9	(+)	+	(+)	+	+	+	+	++	+	+
S10	+	+	(+)	+	-	+	(+)	++	(+)	+
S11	(+)	+	+	+	(+)	+	(+)	++	+	+
S12	(+)	+	+	+	+	+	(+)	++	+	+++
S13	-	+	(+)	+	+	++	(+)	++	-	++
S14	-	+	(+)	+	-	+	(+)	+	-	+
S15	-	+	-	+	-	+	(+)	++	-	+
S16	+	+	-	+	(+)	+	(+)	++	-	+
S17	-	(+)	-	(+)	-	-	(+)	+	-	+
S18	-	+	-	(+)	-	+	+	++	-	++

Tentativeness

The students (n: 11) had naive or mixed views related to tentativeness at the beginning of the study. They mostly believed that scientific knowledge is absolute and not subject to change. In the first activity where the tentativeness of science is emphasized, a dialogue between researcher and student in the introductory stage is shown students' naive views about tentativeness.

Researcher: (Black hole figure is shown) "Anyone have any idea what this photo is?"

S18: "It is Black hole, I saw on the news."

Researcher: "Can we see the black holes with our eyes? How could they have taken this picture?"

S18: "No, we can't. They could've taken with a telescope."

Researcher: "How did the telescope contribute to the development of scientific knowledge about astronomy?"

S18: (No answer)

Researcher: "So, do you think that with a more advanced telescope, what we know about space today, can change in the future?"

S18: "It doesn't change anymore; I think they've seen everything."

After STEM-based NOS instruction, most of the students (n: 16) were in the range of informed views. They thought that scientific knowledge is tentative and might revise or change with the new evidence and development of technology. The dialogue related to this theme between the researcher and a student in the same activities' reflection stage is as follows. Students created their own telescopes with using mathematics and engineering designs, and they successfully found the connection between tentativeness and STEM disciplines.

Researcher: Is there anyone who can tell us how you used engineering and mathematics skills to design your own telescope?

S1: "First we draw, then we combined the materials. I think this was an engineering job. After, we measured the distance between the lenses to make the design, we made some trials, so we used mathematics. Then, we designed our model."

Researcher: "So, was the design you originally drew and the you created in the final different from each other?"

S1: "Yes, we had a very different design when we first drew it. First, we had an inverted and blurry image. Then we measured it again, cut it, changed a lens, and so on. We made our telescope to a flat and clearer image."

Researcher: "Is there anything about astronomy might be different from what we know today? Can you claim that what we know about the sky is definite and unchangeable?"

S1: "No, I don't think so, maybe if we look through a more advanced telescope, we can see that everything is different in the future."

S4: "Like we did in the activity. Our design has changed, so everything might be change."

Researcher: "How can technology, engineering, and mathematics affect the development and change of scientific knowledge about astronomy?"

S1: "Telescopes made with advanced technologies allow us to make better observations, enabling us to gain new information and perhaps change what we know. Engineering skills and some calculations are required to make these telescopes."

Empirical Basis

At the beginning of the study, most of the students had (n: 13) naive view of the empirical basis of scientific knowledge. They thought that scientific knowledge is only based on experiments. Also, they believed that everything might be science if a scientist does it.

After STEM-based NOS instruction, most of the students (n: 15) realized that science is based on empirical evidence, and it is also based on observations (direct or indirect) and inferences. They expressed scientific knowledge is supported by empirical evidence, but never proven 100%. The dialogue between the researcher and the students related to the empirical basis of science and its relation to other STEM disciplines during the teaching of conservation of energy activity's reflection stage is as follows.

Researcher: "Why did the marbles you use on the skateboard you designed stop moving after a while?"

S5: "Due to friction. All the energy in the marble turned into heat energy at the end."

Researcher: "Can we see the energy transformation that you're talking about with naked eyes?"

S5: "No, it's an indirect observation. We're experimenting and observing. We cannot see that the energy is transforming, but we say it based on the effects"

Researcher: “What kind of effects?”

S5: “For example, when the marble slides from the top down, it does not stop, but it continues to enter on a flat surface for a while. So, its potential energy is transformed into motion energy. By the way it was super cool, I definitely enjoyed it!”

Researcher: “It is good to hear that… Well, what can be done to maximize energy use? Do engineers use this knowledge of energy conversion to make various designs?”

S7: “Of course. Engineers, for example, use this information when making roller coasters.”

Researcher: “Do they need to make mathematical calculations in this process?”

S7: “Yes. There are certain formulas of potential and kinetic energy. We tried to adjust the heights at the points where the marble changed direction so that the marble would go for a long time. It is all about math.”

Researcher: “Well, how do activity you did today and scientist do their investigations relate to each other?”

S5: “We designed skateboards, and then we did some trails, there are some numbers that we observed during the activity, based on these numbers we concluded and stated our claim about the transformation of energy. We did not get rid of anything, we always talked about our data and supported our claims with evidence. That is how science work.”

Observation/Inferences

Students (n: 12) mostly had inconsistent and naive views related to importance of and difference between observation and inference at the beginning of the study. They often express their personal interpretations as an observation.

After STEM-based NOS instruction, most of the students (n: 15) developed their understanding of observation and inferences. They realized the difference between observation and inferences. They stated that observations are process that can be accessed directly with senses and describe natural phenomena, and inferences are propositions that cannot be reached directly with our senses. Related to the observation/inferences and its relation to STEM disciplines in the circuit activity’s reflection stage is shown in the below dialogue between the Researcher and students:

Researcher: “Is there anyone see directly whether the electric current passes through matter?

S13: No, we did not, we observed them indirectly.”

Researcher: “What do you mean?”

S13: “In the circuit we designed, we understood that the current passed through the wire and reached the bulb by the lighting of the bulb.”

S3: “We did experiment with the circuit in which we designed whether various materials are conducting or non-conducting.”

Researcher: “Is the eraser conducting or non-conducting?”

S3: “Eraser is a non-conducting material.”

Researcher: “Is this an observation or inference?”

S3: “This is my inference. We made observations, like when I put the eraser just middle of the wires, the bulb didn't light so we inferenced that it is non-conductive.”

Creativity/Imagination

At the beginning of the study, unlike the other aspects of NOS, there was no student in the naïve range. However, most of the students (n: 14) had inconsistent view about the role of creativity and imagination in scientific research. They mostly believed that scientists limited when they use creativity and imagination in some parts of a scientific study. In the young histologists activity where the creativity/imagination aspect is emphasized, a dialogue between Researcher and a student in the introductory stage is presented below:

Researcher: “Can we see the cells with our eyes?”

S16: “No, we can't.”

Researcher: “How could scientific knowledge about the structure of the cell be obtained?”

S16: “Scientists see the cells by using a microscope.”

Researcher: “So, can we say that technology is effective in the development of scientific knowledge about the cell?

S16: Sure. With microscope technology improves more, clear images have been obtained and new information has been revealed about the cell.”

Researcher: “Do scientists use their imagination and creativity in the process of presenting scientific information about the cell?”

S16: “I think they can use, but they might have used it only in the beginning of the investigation.”

After STEM-based NOS instruction, almost all students (n: 17) improved their views of creativity and imagination in science. They stated that scientists use their imagination and creativity at all stages of their research, and that scientific explanations are more invented than discovery and require considerable imagination and creativity. The dialogue between the Researcher and a student related to the creativity/imagination in the reflection stage of the “young histologists” activity is shown as follows.

Researcher: “I see that the cell models you designed are different from each other. You made different designs with the same information, why are these all different?”

S16: “Everyone use the imagination/creativity, that's why these are different.”

Researcher: “Do scientists use their imagination and creativity when they are doing their research about the cell?

S16: They used it; even Robert Hook used his creativity to give his name to the cell. He likened the mushroom pores to the chambers’ rooms.”

Researcher: “Do you think that scientists also use their imagination and creativity in interpreting observations made with a microscope?”

S16: “Yes definitely, creativity and imagination play a crucial role in every scientific research and investigation like we used in designing our own cell model.”

Subjectivity/Theory-Laden

Students (n: 11) had mostly naive and mix views related to subjectivity and theory-laden aspect of NOS at the beginning of the study. They thought that scientific knowledge was objective and that scientists could not be subjective. They considered that the differences of opinion among scientists who researched the same subject were due to lack of sufficient data. After STEM-based NOS instruction, all students (n: 18) improved their understanding of subjectivity. They stated that scientific knowledge is influenced by scientists’ other experiences, socio-cultural background, beliefs, and theoretical acceptance. The dialogue between the Researcher and a student related to the subjectivity/theory-laden NOS aspect in the reflection stage of circuit activity is shown as follows.

Researcher: “We learned that Edison and Tesla had different ideas about the transport of electric current. Why do you think they had so much conflict on the same subject? What could be the reason for having different scientific knowledge on the same subject?”

S12: “There may be different opinions, there are still different opinions on how to transport electric current wirelessly in the most efficient way and discussions are continuing.”

S7: "Every scientist has a different background, education and view. Everyone is looking from his own point of view. As we mentioned in the activity, Edison apparently didn't want to accept anything that contradicted his own work. That was his character."

Researcher: "Does this change the fact that they do scientific research?"

S12: "No, there are different opinions, but that does not mean that they are not scientific. He has his own evidence."

Researcher: "Is the fact that the lightening tools you created differ from each other in relation to your previous experience or knowledge?"

S12: "Yes, there is. We all have different imaginations and background knowledge. Scientists are always influenced by their previous experiences and knowledge as they produce information; like we did…with this, engineers design something new, or produce new technology."

Table 2. 7^{th} Grade Students' Representative Views of Targeted NOS Aspects

NOS Aspects	Naive or Mix Views	Informed Views
Tentativeness	The information in the science books doesn't change, because they found it once, and they proved it." (Pre-Interview_S1) "Only some scientific knowledge may change, but not all." (Pre-VNOS_S12)	"Scientific knowledge may change in the future with the new data and evidence. For example, studies on the structure of the cell has developed and previously known information has changed with the development of new microscopes; such as, the atom has first been likened to a sphere, then defined as a cloud, and has become the current one." (Post-Interview_S1).
Empirical based	"Astrology is a scientific field because many people believe in it. I think scientists have made up theories about the extinction of dinosaurs." (Pre-Interview_S6)	"Science is based on experiments, observations and inferences. Thus, astrology is not a scientific endeavor." (Post-VNOS_S4)
Observation/ Inferences	"Observations are the interpretations obtained as a result of experiments." (Pre-Interview_S8)	"Observations are data that collected with our sensory organs without making any inferences. Inferences are the interpretations based on these observations. In our lesson we created the atom model, we made observations about the atom models created in the past and then we created our own model." (Post Interview_S6)
Creativity/ Imagination	"Researchers should not use their imagination and creativity to produce scientific knowledge. Otherwise it is not scientific. Science is a serious thing." (Pre-VNOS_S2)	"Scientists may have put what the dinosaurs look like by first joining their bones and then adding the appearance of the skin in the computer, with their imagination. They use their imagination and creativity at every stage of an investigation." (Post-Interview_S7)

Subjectivity/Theory-laden	"Researchers have a different opinion about the dinosaurs because there is no evidence of. If there were evidence, they would be completely agreed about the extinction of dinosaurs. It's impossible for scientists to come up with different things by looking at the same things" (Pre-VNOS_S2)	"It is possible for scientists to say different things by looking at the same things, because their backgrounds or study fields might be different, or they might look at the things from different angles. They have different educational, cultural or religion background." (Post Interview_S13)

It is possible to see the effectiveness of STEM-based NOS teaching in students' interviews as well as the development of their NOS views. During the post interviews, when the students were asked which part of the course, they liked the most and in which part they learned more, they mostly stated that they learned at all stages of the lesson but they were quite entertained and learned in STEM based NOS activities (inquiry stage).

> *"The whole lessons were really fun. I wish all our lessons were like this. We produced new things, like a scientist, or an engineer, we designed and created our models. I was a bit scared of science, but after this lesson, I saw that science was nothing to be afraid of, and it was very enjoyable." (Post-Interview_S11)*
>
> *"I mostly enjoyed in the activity time when I did. In fact, the very beginning of the lesson was also interesting, but I was very excited when I produced the models, especially when I made telescopes." (Post-Interview S3)*

In addition, the students expressed that they were especially curious about where mathematics would be used in daily life, and that they liked to see examples to answer it. Also, some students emphasized the importance of formative assessment, and stated that they learned quite a lot in the reflection stage.

> *"We always ask our math teacher why we are learning the math? Where will we use it? For the first time in my life, I produced something by using mathematics. For example, in the telescope model, the groups who could not do right math in locating the lenses, they did not approach objects as much as ours." (Post-Interview_S5)*
>
> *"I mostly learned at the end of lesson. The assessment questions that we respond together gave us a better understanding of what we learned." (Post-Interview_S4)*
>
> *"In the questions you gave us at the end of the lesson, we saw the summary of all the things we did and understood better why we did it." (Post-Interview_S9)*

Discussion, Conclusion and Recommendations

This study was planned to examine the influence of STEM-based NOS teaching on 7th grade students' NOS views. Although we agree that the explicit/reflective approach is effective for teaching

NOS (e.g., Khishfe and Abd-El-Khalick, 2002; Lederman and Stefanich, 2006; Schwartz, Lederman and Crawford 2004), our mind is still blurred as to whether the standard explicit/reflective approach can improve students' views to the desired level. Therefore, this study aimed to teach the targeted NOS aspects in an explicit/reflective manner by using STEM-based contextualized NOS activities. In particular, it is aimed for students to find a connection between STEM disciplines and targeted NOS aspects and to realize activities by feeling themselves like scientists, engineers, mathematicians or technologists and to understand NOS from their point of view. In this sense, this study differs from the other NOS teaching studies.

The meaning of the STEM teaching for a science educator and science teacher should be to teach science while making connections with other STEM disciplines (Akerson et al., 2018). Unfortunately, in the current STEM movement, STEM is considered as a separate discipline, and science educators are expected to provide STEM education to science teachers and science teachers to students. This situation causes NOS teaching and its importance to remain in the background according to STEM education (Akerson et al., 2018). In order to avoid NOS teaching in the background of the popular STEM movement in the literature, science educators and teachers should understand the STEM-NOS relation well. NOS discipline is already very suitable for teaching when establishing STEM connections. The fact that The Next Generation of Science Standards' Science and Engineering Practices and Crosscutting Concepts section contains the various NOS aspects that students are expected to conceptualize also supports the fact that the two are closely intertwined (Akerson et al., 2018).

According to results of this study, it can be said that this study is quite effective considering that no student is left within the naive range at the end of STEM-based NOS teaching and all improve their views dramatically. Throughout the NOS teaching cycle (Akerson et al., 2010) that enables us to make more conscious and planned progress during the teaching, we taught targeted NOS aspects explicitly/reflectively by associating science with other STEM disciplines. There are some possible factors, which may affect this success. First, it was seen that students had a lot of fun in STEM activities as stated in recent studies (e.g., Canbazoğlu-Bilici and Ünal, 2015; Gökbayrak and Karışan, 2017). In particular, students were entertainingly able to design and develop new products such as an engineer using their existing knowledge, and to establish a better understanding of targeted NOS aspects by relating other STEM disciplines. They had so much fun doing it. Second, the motivation and interest of students to participate in our teaching of NOS may have an impact on the significant development of students' NOS views although a few activities we offer them. The students pretty much liked these STEM-based NOS activities, and showed high participation. Another factor might be the importance that we gave to the reflection part in this STEM based NOS teaching with the help of instant feedbacks, which reinforced the students' learning and helped them understand how much they understood. In parallel to the studies that show that formative assessment is effective in teaching

NOS (Bennett, 2011; Özer, Doğan, Yalaki, and Cakmakci, 2019), we can say that the formative assessment is one of the factors that have the potential to effect of the success in developing students' NOS views.

As Akerson and her colleagues (2018) stated, we think that STEM is not a separate discipline and there should be no development of students' STEM views. Students may develop and progress separately in the disciplines constituting STEM. If students are expected to learn STEM as a separate discipline, they need to be educated about the nature and interconnection of each of the STEM disciplines (Akerson et al., 2018). Obviously, it may not be right to expect this to be done with science teachers who have had limited mathematics and technology education during their undergraduate education and have never received engineering education (Akerson et al., 2018). Therefore, as in this study, it should be considered STEM as an effective approach in science education and to revise the expectations for teachers in terms of using STEM effectively as an educational approach.

Teaching NOS aspects are very suitable when establishing STEM connections and the creativity, critical thinking and problem-solving skills targeted in STEM applications are closely related to the NOS aspects. These skills are possible for individuals who are aware of the fact that scientific knowledge can be changed and that scientific knowledge is subjectively put forward and influenced by the socio-cultural context. Also, individuals who are aware of the fact that scientific knowledge includes the imagination and creativity of scientists and that the same scientific knowledge can be obtained in different ways are likely to adopt more creative ways when using this knowledge in a scientific research. For these reasons, STEM-based NOS teaching may provide successful results in NOS teaching. We also think that using STEM approach in NOS teaching can increase students' interest and participation in NOS activities and thus the development of NOS views. In this sense, it is recommended that STEM-based NOS activities are necessary to be expanded and investigate in the future studies. It is also recommended to examine the permanence of NOS views of students in the long term when using this approach because recent literature showed one course is not enough for developing students' NOS views even using explicit/reflective NOS instruction (Akerson et al., 2005).

In general, in NOS teaching, there is a need to talk about different things and try different methods from new perspectives (Akerson, Buck, Donnelly, Nargund-Joshi and Weiland, 2011; Clough, 2018). In this research, it was presented a new and different perspective to science educators and teachers that they can use in NOS teaching. As a popular research area, the STEM approach does not require to put NOS teaching in the backseat. STEM and NOS can be handled together in science classes in a way to feed each other. As shown in this study, the STEM approach can be used as an effective tool in NOS teaching. This study might give teachers an idea of how these two can be handled together in science classes without putting NOS in the backseat. In this study, it was presented an example to guide science teachers, who are expected to include both the NOS aspects and STEM in their courses by various authorities, on how they can teach the NOS aspects while teaching science content in relation to other STEM disciplines in an explicit/reflective way. Thus, teachers and science educators are invited to try STEM approach in their classrooms for developing students' NOS views.

References

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

Abd-El Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 295-317.

Akerson, V. L., Burgess, A., Gerber, A., Guo, M., Khan, T. A., & Newman, S. (2018). Disentangling the meaning of STEM: implications for science education and science teacher education. *Journal of Science Teacher Education, 29*(1), 1-8.

Akerson, V.L., Elcan Kaynak, N., & Avsar Erumit, B. (2019) Preparing preservice early childhood teachers to teach nature of science: Writing children's books. *Innovations in Science Teacher Education, 4(*1). Retrieved from https://innovations.theaste.org/preparing-preservice-early-childhood-teachers-to-teach-nature-of-science-writing-childrens-books

Akerson, V. L., Morrison, J., & McDuffie, A. R. (2005). One course is not enough: pre-service elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*(2),194–213.

Akerson, V. L., Weiland, I. S., Pongsanon, K., & Nargund, V. (2010). Evidence-based strategies for teaching nature of science to young children. *Journal of Kırsehir Education, 11*(4), 61-78.

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. Science Education, 95(3), 518–542.

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

Mesci, G. (2016). Preservice science teachers' pedagogical content knowledge for nature of science and nature of scientific inquiry: A successful case study. PhD dissertation, Western Michigan University, USA. http://scholarworks.wmich.edu/dissertations/1606

Mesci, G., & Schwartz, R. S. (2017). Changing preservice science teachers' views of nature of science: why some conceptions may be more easily altered than others. Research in Science Education. 47(2), 329-351., Doi: 10.1007/s11165-015-9503-9

Mesci, G. (2020). The influence of PCK based NOS teaching on pre-service science teachers' NOS views. Science & Education. Doi: 10.1007/s11191-020-00117-7

Bell R. L., Mulvey, B. K., & Maeng, J. L. (2016). Outcomes of nature of science instruction along a context continuum: preservice secondary science teachers' conceptions and instructional intentions. *International Journal of Science Education, 38*(3), 493-520.

Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The Science Teacher, 72*(7), 30-33.

Bennett, R.E. (2011). Formative assessment: A critical review. *Assessment in Education: Principles, Policy & Practice, 18*(1), 5-25.

Breiner, J., Harkness, S., Johnson, C. C., & Koehler, C. M. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics, 112*(1), 3-11.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn.* Washington, DC: National academy press.

Canbazoglu-Bilici, S. & Unal, A. (2015). Integration of media design processes in science, technology, engineering, and mathematics (STEM) education. *Eurasian Journal of Educational Research, 15*(60), 221-240.

Capps, D., & Crawford, B.A. (2013). Inquiry-based Instruction and Teaching about Nature of Science: Are They Happening? *Journal of Science Teacher Education,* 24, 497-526.

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science & Education*, *15*(5), 463-494.

Clough, M. P. (2018). Teaching and learning about the nature of science. *Science & Education,* 27, 1-5.

Creswell, J.W. (2007). *Qualitative inquiry & research design: Choosing among five approaches.* Thousand Oaks, CA: Sage Publications.

Çorlu, M. S., Capraro, R. M. & Capraro, M. M. (2014). Introducing STEM education: implications for educating our teachers for the age of innovation. *Education and Science, 39* (171), 74-85.

Derin, G., Aydın, E., & Kırkıç, K. A. (2017). A scale on the attitudes towards STEM education. *El-Cezeri Journal of Science and Engineering, 4*(3), 547-559.

Erduran, S., & Dagher, Z. R. (2014). *Reconceptualizing Nature of Science for Science Education* (pp. 1-18). Springer Netherlands.

Gökbayrak, S., & Karışan, D. (2017). Exploration of sixth grade students' views on STEM based activities. *Journal of Field Education Researches, 3*(1), 25-40.

Guskey, T. R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.

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

Karakaş, M. (2017). Turkish students' views on nature of science. *European Journal of Education Studies, 3(*10), 176-183.

Keçeci, G., Alan, B., & Kırbağ-Zengin, F. (2017). STEM education practices with 5th grade students. *Journal of Kirsehir Education Faculty, 18*(1), 1-17.

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

Khishfe, R., & Lederman, N. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching*, *43*(4) 395-418.

Kruse, J., Kent-Schneider, İ., Zacharski, K., & Rockefeller, M. (2019). Investigating the effect of NOS question type on students' not responses. *Paper Presented at the 2019 Annual Conference of the Association for Science Teacher Education (ASTE) in Savannah, GA.*

Lederman, N. G. (2007). *Nature of science: Past, present, and future.* In S. K. Abel & N. G. Lederman (Eds.). Handbook of research on science education, (pp. 831– 879). Mahwah, NJ: Erlbaum.

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

Lederman, J. S., & Khishfe, R. (2002). Views of nature of science, Form D. Unpublished paper. Illinois Institute of Technology, Chicago, IL.

Lederman, N. G., & Lederman, J. S. (2012). *Nature of scientific knowledge and scientific inquiry: Building instructional capacity through professional development.* In Fraser, B. J., Tobin, K. G., & McRobbie, C. J. (Eds.). Second International Handbook of Science Education, (p. 335) Springer International Handbooks of Education 24, DOI 10.1007/978-1-4020-9041-7_24, © Springer Science+Business Media B.V. 2012

Lederman, N., & Lederman, J. (2014). *Research on teaching and learning of nature of science.* In N. Lederman and S. Abell (Eds.). Handbook of Research on Science Education, (pp. 600-620). New York: Routledge.

Lederman, J. S., & Stefanich, G. P. (2006). *Addressing disabilities in the context of inquiry and nature of science instruction.* In L.B. Flick & N.G. Lederman (Eds.), Scientific inquiry and nature of science (pp. 55-74). Springer, Dordrecht.

McDonald, C. V., & McRobbie, C. J. (2012). *Utilising argumentation to teach nature of science.* In B. Fraser, K. Tobin, & C. McRobbie (Eds.), Second international handbook of science education (pp. 969–986). Dordrecht: Springer.

McMillan, J. H., & Schumacher, S. (2010). *Research in Education: Evidence-Based Inquiry,* My Education Lab Series. Pearson.

Ministry of National Education [MoNE] (2013; 2018). *İlköğretim kurumları fen bilimleri dersi öğretim programı [Primary education institutions' science instruction program].* Ankara, Turkey: Talim Terbiye Kurulu Başkanlığı.

Murphy, C., Smith, G., & Broderick, N. (2019). A Starting Point: Provide Children Opportunities to Engage with Scientific Inquiry and Nature of Science. *Research in Science Education,* 1-35. https://doi.org/10.1007/s11165-019-9825-0

NGSS Lead States. (2013). *Next generation science standards: for states, by states.* Washington, DC: National Academies. http://www.nextgenscience.org/next-generation-science-standards. Accessed 21 October 2013.

Olson, J.K. (2018). The inclusion of the nature of science in nine recent international science education standards documents. *Science & Education,* 27, 637. https://doi.org/10.1007/s11191-018-9993-8

Özer, F., Doğan, N., Yalaki, Y., Irez, S., & Çakmakci, G. (2019). The ultimate beneficiaries of continuing professional development programs: Middle school students' nature of science views. *Research in Science Education,* 1-26. https://doi.org/10.1007/s11165-019-9824-1

Park, H., Nielsen, W., & Woodruff, E. (2014). Students' conceptions of the nature of science: perspectives from Canadian and Korean middle school students. *Science & Education, 23* (5), 1169-1196.

Ricks, M. M. (2006). *A study of the impact of an informal science education program on middle school students' science knowledge, science attitude, STEM high school and college course selections, and career decisions.* [Doctoral Thesis. The University of Texas].

Schwartz, R. S. (2007). Beyond evolution: a thematic approach to teaching NOS in an undergraduate biology course. *Proceedings of the international conference of the National Association for Research in Science Teaching, New Orleans, LA. April 15–18.*

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Tseng, K. H., Chang, C. C, Lou, Ş. J. & Chen W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal Technology Design Education,* 23, 87-102.

Yamak, H., Bulut, N., & Dündar, S. (2014). The impact of STEM activities on 5th grade students' scientific process skills and their attitudes towards science. *Journal of Gazi Educational Faculty,* 34(2), 249- 265.

Yager, R.E., & Brunkhorst, H. (2014). *Exemplary STEM programs: Designs for success.* Virginia USA: NSTA Press, National Science Teachers Association.

Appendix

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STEM-based NOS activity: Make your own Telescope

Space Research Unit of 7th grade science lesson objectives:

- F.7.1.1.3. Explain the relationship between technology and space research,
- F.7.1.1.4. Explain the structure of telescope and what it does,
- F.7.1.1.5. Make inferences about the importance of telescope in the development of astronomy, and
- F.7.1.1.6. Prepare and present a simple telescope model (MoNE, 2018, p.39).

The NOS goals:

- Comprehend that scientific knowledge may change in the light of new data and technology by seeing that their models change during telescope design and creation.
- Realize that they use their imagination and creativity in the design and creation of the telescope.
- Comprehend the subjective and theory-laden structure of scientific knowledge by seeing and applying different types and designs of telescopes.
- Understand that science is based on direct /indirect observations and inferences obtained from the observers by examining the relations between telescope and space research and comprehends the evidence-based empirical structure of science.
- Comprehend that different inferences about black holes can be made with the same observations.

</td></tr>
<tr><td>Stages</td><td colspan="2">Instruction</td></tr>
<tr><td>Introductory Stage</td><td>

A color printout of the black hole photograph (as depicted in the first image released by the event horizon telescope in April 2019) was shown to the students and a classroom discussion was initiated with the following questions.

- Has anyone seen this photograph before?
- How do you think this photo was taken?
- How do we see objects at a distance that is impossible to *see* with the naked eye?

After the discussion about the above questions, the researchers handed out a note about two important theories of "Albert Einstein" and "Stephen Hawking" about black holes.

</td><td>

Information Note / Black Holes

Albert Einstein's Black Hole Theory

According to Einstein's theory of relativity, anything that enters the black hole is destroyed and lost. However, Einstein's theory contradicts the "quantum theory", which asserts that information in the universe will never be lost. Scientists have described this situation as a "paradox of loss of information", which they have not been able to combine since the 1970s.

Stephen Hawking's Black Hole Theory

Hawking, in his statement about black holes in August 2015, stated that there is no "black hole" that destroys the things. If it returns, he said that it surely provided a transition to a different universe, but that there was no return from this universe. Hawking's statement contradicts Einstein's statement.

Although Hawking's statement that the object entering the black hole does not disappear, it contradicts what Einstein said. Hawking presented a solution by stating that the paradox about the loss of information that the quantum theory and the relativity theory contradicts does not pass through the black hole and that it is hidden in the event horizon.

</td></tr>
<tr><td>Inquiry Stage</td><td colspan="2">After revealing students' prior knowledge and made them to think about different theories, the "student activity paper" was handed out to the students. The students were reminded that they are a scientist today and they were asked to design a telescope model that they would use during their sky research.</td></tr>
</table>

	The instructions in the activity paper were explained to the students and they were asked to draw the telescope model they would design on the activity paper and then compare and discuss their models with the group friends. The materials that can be used in the design of the model were provided by the Researchers before the course and placed on a suitable table for the students to select.
	Student Activity Paper
	Instruction 1: Dear little scientist; you are required by the Space Research Unit to design a telescope model to detect the motion of planets and stars in space. This model will help scientists to understand space better. Now draw a picture of the telescope you intend to design in the space below. **Drawing 1:**
	Instruction 2: Now, come together with other scientists in your group and compare the telescope design you have drawn.
	Instruction 3: Now, in agreement with your group friends, draw a picture of the telescope you will make with the materials that provided. **Drawing 2:**
	Instruction 4: Now, you can start to make your own telescope. If you make any changes to the design you made while making the model, make a note of these changes in the field below.
	After deciding on the final form of the telescope, the students started to design the telescope models. Students were asked to take notes of their measurements while designing their models. In particular, the importance of the distance between the lenses (focal length) is emphasized. After the models were designed, each group was allowed to present their models and explain the measurement they did. 
Reflection Stage	During the inquiry stage, students were asked to make inquiries that would enable them to associate their research with the targeted aspects of the NOS and other STEM disciplines. In this process, it is aimed that the students understand the relationship between the NOS aspects and STEM disciplines. *Associating the NOS with STEM Disciplines:* • The difference between the individual designs and the final designs and the changes of the models were emphasized and how the scientific knowledge changed and developed in the line with the new data and ideas. • Similarly, it was emphasized the importance of observations and inferences in science and that students design this model with observation, experience and inferences. • Different views about black holes were mentioned through the black hole image presented during the introductory stage of the activity and it was emphasized that different inferences could be made with the same data. Here, it is emphasized that the individual and socio-cultural differences of scientists, and their fields of study affect their research, and that scientific knowledge is subjective in this respect. • As a result of the emergence of different designs, it was emphasized that the students' own imagination and creativity plays an important role in the formation of these designs and that they might have the effect of having different experiences or

	adopting different theories. Also, it was argued that science is based on direct or indirect observations and inferences by examining the relations between telescope and space research and understands the empirical structure of scientific knowledge. • Specifically, it is stated that mathematics is important in revealing telescope models and that different measurements or mathematical differences make a difference in the products and this directly affects the technological product. *Researcher: Is there anyone who can tell us how you used engineering and mathematics skills to design your own telescope?* *Student: First we draw, then we combined the materials. I think this was an engineering job. After, we measured the distance between the lenses to make the design, we made many trials, so we used mathematics. Then, we designed our model.* *Researcher: So, was the design you originally drew and the you created in the final different from each other?* *Student: Yes, we had a very different design when we first drew it. First, we had an inverted and blurry image. Then we measured it again, cut it, changed a lens, and so on. We made our telescope to a flat and clearer image.* *Researcher: Is there anything about astronomy might be different from what we know today? Can you claim that what we know about the sky is definite and unchangeable?* *Student: No, I don't think so, maybe if we look through a more advanced telescope, we can see that everything is different in the future.* *Students: Like we did in the activity. Our design has changed, so everything might be change (Tentativeness of scientific knowledge-informed)* *Researcher: How can technology, engineering, and mathematics affect the development and change of scientific knowledge about astronomy?* *Student: Telescopes made with advanced technologies allow us to make better observations, enabling us to gain new information and perhaps change what we know. Engineering skills and some calculations are required to make these telescopes.* *Researcher: Did you make experiment with this activity?* *Student: No, we have made observations, we have brought together what we have already known and what we have learned and formed our model. (Observation and Inference - informed)* *Researcher: Did you use your imagination?* *Student: Yes, we all have different models. I think our imagination affected our model because we are different from each other, we have produced different products. (Imagination and creativity-informed)* *Researcher: So, as we mentioned at the beginning of the lesson, could you tell us what might influence Einstein and Hawkings to have different findings?* *Student: They made observations. They made inferences from their observations. (Observation and inference-infromed)* *Student: They are also different people. Their imaginations are different, their backgrounds are different. It's normal for them to think differently. (Subjectivity-informed)*

Student assessment papers were distributed to the students whether they have learned the subject of science, NOS aspects, and the relationship between the subject and other STEM disciplines.

Student Assessment Paper

Q1. In ancient times, many scientists believed that the Earth was the center of the universe that the Sun, Moon and stars revolved around the Earth. This model is called the Earth-cente universe model. After the 16th century, with the invention of the telescope and its use in observation research, scientists such as Copernicus, Galilei, and Kepler have demonstrated w various evidence that the Earth and other planets rotate in orbits around the Sun, and this mod which scientists reveal, is called the Sun-centered universe model. Towards the end of the 1 century, when William Herschel researched the Milky Way Galaxy, which included the So System, they found that the pale light gas and dust clouds they observed were other galax beyond the Milky Way. Towards the middle of the 19th century, astronomers adopted the idea a vast universe with infinite dimensions.

Accordingly, which of the following statements are true (T) and which are false (F)?

(…) Scientific knowledge does not change.

(…) Scientific information is based on direct / indirect observations and inferences derived fr observations.

(…) Scientific knowledge may change with the development of technology or the emergence new evidence.

(…) Scientific knowledge is objective, which means it is not influenced by scienti imagination and creativity.

(…) Different inferences can be made using the same data.

Q2. Which of the following are direct observations, which are indirect observations and wh are inferences?

	Direct Observation	Indirect Observation	Inference
Going on the roof in the evening to look at the stars.			
The telescope has lenses of different sizes.			
I think the telescope is very important for sky research.			
As a sailboat moves away from the sea, it first leaves the field of view of the hull, then shrinks out of sight.			
When the sailboat moves away from the sea, the hull and then the sail shrinks out of our field of view, indicating that the world is not			

<table>
<tr><td rowspan="5"></td><td>flat.</td><td></td><td></td><td></td></tr>
<tr><td>An object caught in a black hole must be disintegrating and disappearing.</td><td></td><td></td><td></td></tr>
<tr><td>My friend used colored cartons to design his telescope.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Q3. What are the contributions of the telescope and other space observation technologies astronomy research?

Q4. How would it affect your activity if you did not use certain technologies (lenses, rul meters, etc.) in your activity today?

Q5. How did you use mathematics in your research?

Q6. Is engineering skills necessary to design a technological telescope? How does the design space observation tools relate to engineering?</td></tr>
<tr><td colspan="4">After the assessment activity was made by the students individually, each question was answered together with the students in the classroom and they were provided with immediate feedback.</td></tr>
<tr><td>Assignment</td><td colspan="4">Please write a daily reflection essay which should include what you have learned today!</td></tr>
</table>