Science & Education (2022) 31:713–737
https://doi.org/10.1007/s11191-021-00274-3

ARTICLE

Using Children's Literature in the Middle School Science Class to Teach Nature of Science

Preservice Teachers' Development of Sources

Banu Avsar Erumit[1] · **Valarie L. Akerson**[2]

Accepted: 7 August 2021 / Published online: 6 September 2021

Abstract
In this study, we report the results of the content analysis of preservice middle school science teachers' own written science storybooks and middle school female students' reflections of five of the books. The participants of this study were 50 preservice middle school science teachers taking a history and nature of science course and 13 sixth-grade female students in a school in Turkey. We report representations of nature of science (NOS) aspects included in the preservice teachers' own written storybooks. Observation and inference was the most commonly included aspect among the NOS aspects, followed by the tentative NOS. We used a qualitative analysis of transcribed classroom discussions around five storybooks used by five preservice teachers in their field experiences. We found that the teachers facilitated explicit reflections about NOS aspects and science content covered in the books. Our findings build on research showing that appropriately designed children's science books can be used as classroom tools for supporting NOS instruction. We found that writing their storybooks and refining their NOS ideas through discussions provides a powerful tool for developing preservice teachers' knowledge about NOS. Preservice teachers facilitated discussions promoting explicit student reflections about NOS aspects and science content using these books.

1 Introduction

An appropriate understanding of the nature of science (NOS) has been recommended for all as a component of scientific literacy (DeBoer, 1991; Hodson, 2009). As Bell (2009) points out, conceptualizing NOS is a component of scientific literacy. Scientific literacy is not an additional component; rather it is a fundamental practice in science education.

If we desire our students to acquire the ability to understand scientific reasoning, we should provide them opportunities to read, write, and communicate science (Osborne, 2002). Writing and presenting scientific information are musts for students to support

✉ Banu Avsar Erumit
banu.avsar@erdogan.edu.tr

1 Recep Tayyip Erdogan University, Rize, Turkey

2 Indiana University, Bloomington, IN, USA

claims in science, express their existing knowledge in science, and transfer their thoughts, imaginations, and experiences into their writings and presentations (NGSS Lead States, 2013). Also, reading, writing, and verbal communication are essential literacy practices for participating in a global society (Krajcik & Sutherland, 2010; Pearson et al., 2010). Whether or not students choose a science-related career, they will always need to read and understand science-related resources throughout their entire lives (Krajcik & Sutherland, 2010).

Comprehending scientific knowledge and proficiency in literacy skills are interconnected, and one would not understand scientific information with limited literacy proficiencies (Casteel & Isom, 1994). Therefore, young children need reading and discussing stories along with science investigations to build scientific literacy (Hapgood & Pallincsar, 2006). The benefits for science knowledge identified from reading such books include deepening understanding, connecting ideas with children's understanding, increasing vocabulary, changing opinions, and increasing achievement in both science and literacy (Casteel & Isom, 1994; Emmons et al., 2018; Hapgood & Pallincsar, 2006; Janke & Norton, 1983; Monhardt & Monhardt, 2000; Mutonyi, 2016; Pringle & Lamme, 2005; Robbins & Ehri, 1994; Royce & Wiley, 1996).

Books that have explicit portrayals of science and scientists could be used to illuminate how science works and how scientists carry out investigations that are otherwise not easily comprehensible to many children (Ford, 2006). Trade and storybooks can be a great source to teach NOS when selected and used watchfully, although they cannot solely characterize the complexities of science (Brunner & Abd-El-Khalick, 2020; Ford, 2006). As Lederman and Lederman (2014) point out, understanding of NOS is not solely adequate to produce scientifically literate citizens. Scientifically literate individuals should have practical understandings of content knowledge, understand how scientific knowledge was developed (to be able to do and know about practices), and have the ability to make informed results about scientifically based personal and public issues along with understanding of NOS (Lederman & Lederman, 2014). Also, these books can support explicit-reflective NOS instruction (Akerson, Avsar Erumit, Elcan Kaynak, 2019). An explicit reflective approach has been previously found to be a practical NOS instructional approach for young children and older children (Akerson et al., 2014; Khishfe & Abd-El-Khalick, 2002; Khishfe, 2012a, 2012b; Khishfe & Lederman, 2007). Considering this fact, we used such instruction to prepare preservice middle school science teachers to create their own NOS storybooks and develop lesson plans to use these books to teach their students.

To develop such books and associated lesson plans, the preservice teachers needed to (1) understand NOS and (2) find ways to embed their NOS understandings into science storybooks. Making their own books and finding ways to convey their NOS knowledge through storybooks can help preservice teachers improve their understandings of NOS aspects (Akerson, Elcan Kaynak, & Avsar Erumit, 2019). What teachers know shapes what and how they teach and what students learn (Gess-Newsome, 2015). From this point of view, we believed that preservice teachers' understanding of NOS might, in turn, shape how preservice teachers prepare to teach sources for teaching NOS, how they enact teaching, and what students learn.

Regarding their understandings of NOS, we specifically used the seven aspects determined to be non-controversial and attainable by K-12 students as shared by Lederman and colleagues (see Lederman, 2007; Lederman et al., 2002; Lederman & Lederman, 2014). These aspects include the following: science is tentative and empirically based; scientists use their creativity and imagination in their scientific work; scientists have subjective views; science is influenced by the social and cultural environment in which it is embedded; inferences are important in creating scientific knowledge, and there is a relation and difference between observation and inference; there is a difference between theory and law, and one does not become another.

This study aimed to explore preservice middle school science teachers' knowledge of NOS portrayed in their own written science storybooks and examine their enactment of reading these storybooks in their field experience. In particular, we aimed to find out explicit and accurate representations of NOS aspects in preservice science teachers' own written NOS storybooks. Also, we aimed to examine middle school students' reflection of NOS aspects addressed in the books when five of these preservice teachers used their written books in the science field experience. The research questions of this study were.

1. How are preservice middle school science teachers portraying NOS aspects in their written books? Which aspects of NOS do these books explicitly and accurately represent?
2. How do sixth-grade students reflect on NOS ideas discussed in such books?

1.1 Literature Review

Science teaching today must go beyond teaching science as a body of knowledge that includes definitions, facts, concepts, theories, laws, etc., and focus more on scientific processes and NOS instruction (Bell, 2009). Many reform documents such as next-generation science standards emphasize the importance of teaching NOS to students as a critical component of scientific literacy (NGSS Lead States, 2013). Below we review prior research on improving teachers' conceptions of NOS and their teaching practices.

1.1.1 NOS Instruction

Science educators have various justifications for teaching NOS, perhaps the most fundamental reasons for teaching NOS are having students develop understandings of the kinds of knowledge scientists develop, what types of questions science could or could not answer, how science is similar to or different from other disciplines, and the types of limitations and strengths it might have (Bell, 2009). Nature of science, in general terms, refers to the epistemology of science or science as a way of knowing or values and views natural to scientific knowledge and its development (Lederman, 1992, 2007; Lederman & Lederman, 2014). In other words, science is composed of several practices and a historical collection of knowledge (NGSS Lead States, 2013).

NOS teaching should begin as early as when science teaching begins. Connecting NOS to science instruction from early grades will support students to continue developing their NOS conceptions over time and help them to improve their NOS understandings to informed levels at higher grades. Previous research suggests focusing on more accessible aspects when teaching NOS to young children, such as observation and inference and empirical evidence, and continue with less accessible aspects later, such as subjectivity, social–cultural NOS, and the distinction between theories and laws (Akerson et al., 2014).

Although many teachers have various or even no intentions for teaching NOS, the methods used in science courses and teachers' use of language transfers an image of NOS to students (Abd-El-Khalick, 2012; Clough, 2006). Thus, how to teach about NOS has always been an issue for teachers (Shi, 2021). Some teachers consider NOS teaching different from regular science teaching practices (Leden et al., 2015). Textbooks that address the final products of science instead of giving details about the process of science or use of cookbook-style laboratory activities are a few examples of how students develop mis/conceptions about NOS (Clough, 2006). Considering that, science educators have sought ways to explain the focal points of NOS, how it should be addressed in science instruction, and suggest some approaches for effective and engaging NOS instruction.

1.1.2 Approaches for Teaching NOS

"The consensus view" or in other words "shared-wisdom view" is one of the most widely adopted views to explain NOS. This view is initially suggested by Lederman and colleagues and based on seven aspects that various disciplines of science commonly possess (Lederman, 2007, 2019; Lederman & Lederman, 2014; Lederman et al., 2002). Other alternative approaches to shared-wisdom view were developed to address different aspects of NOS (e.g., Allchin, 2011; Erduran & Dagher, 2014; Erduran et al., 2019; Irzik and Nola, 2011; Kaya & Erduran, 2016). The family resemblance approach is a commonly adopted view that considers variations within science disciplines while recognizing common features or family resemblance among disciplines. This approach is based upon the work of Irzik and Nola (2011) and was developed by Erduran and colleagues (Erduran & Dagher, 2014; Erduran et al., 2019).

While several approaches have been used to provide effective NOS teaching, studies continue to show that learners have a limited understanding of NOS on some aspects of science (see Lederman & Lederman, 2014). Even students from science majors can express NOS aspects only to some extent (Akgun & Kaya, 2020). Although interventions can enhance students' views of NOS in the short term, retaining such understanding in the long term is questionable (Yacoubian, 2021). Emerging research, therefore, needs to reflect on what to teach about NOS and seek more strategies for effective NOS instruction. Using literacy for teaching NOS, for example, has been one strategy used in emergent studies. For example, within literacy and NOS studies, Khishfe (2012a) discussed using argumentation for enhancing learners' NOS understandings. Brunner and Abd-El-Khalick (2020) discussed using trade books in improving teachers' views on some NOS aspects. Akerson, Avsar Erumit, and Elcan Kaynak (2019) explored using children's books to enhance preservice early childhood teachers' NOS conceptions. With this in mind, we asked preservice middle school science teachers participating in history and nature of science classroom to use a literacy-based contextualized explicit-reflective NOS instructional approach and use children's literacy by developing science storybooks. More specifically, we used preservice teachers' own written NOS storybooks as assessment tools by focusing on preservice middle school science teachers' conceptions of NOS as represented in their storybooks. Afterward, we examined middle school students' reflections on NOS aspects when five preservice teachers used storybooks in their science field experience.

2 Theoretical Framework

The present study utilized a literacy-based contextualized explicit-reflective NOS instructional approach as the theoretical framework. Three elements ground the study; the first is consensus view or in other words shared-wisdom view for teaching NOS (Abd-el-Khalick, 2012; Lederman, 2007; Lederman & Lederman, 2014; Lederman et al., 2002); the second is explicit-reflective NOS teaching that is contextualized in a science content, and the third is integrating children's literacy, namely, storybooks in NOS teaching.

2.1 Shared Wisdom View for Teaching NOS

Although there is not an agreed-upon single definition of NOS, there are shared wisdom about the key aspects of NOS that are accepted by scientists, historians, and philosophers and considered as most practical in school settings, non-controversial, and useful in developing scientific literacy (Abd-el-Khalick, 2012; Bell, 2009; Brunner & Abd-el-Khalick, 2017; Lederman, 2007; Lederman et al., 2002; Lederman & Lederman, 2014). The aspects emphasized in shared wisdom view include the following: science is tentative and open to revision in light of new evidence; science is a product of human creativity and imagination; science is based on empirical evidence that is derived from observations and experiments; science is a human endeavor (subjective) and scientists are guided by their backgrounds, mindsets, expectations, views, and values; science is socially and culturally embedded, and scientific knowledge and its practitioners are influenced from various elements of a culture in which scientific knowledge is created and practiced; there is a distinction and relation between observations and inferences in that observations are statements about natural phenomena that are accessible to our five senses while inferences involve interpretation and making sense of observations, often informed by prior knowledge and experiences. There is a distinction and relation between theories and laws that is similar to the connection and difference between observations and inferences whereby laws are descriptive statements of observable phenomena, often expressed mathematically as a relationship, while theories are inferred explanations of observable phenomena (Abd-El-Khalick, 2001, 2012; Lederman, 1992; Lederman, 2007; Lederman et al., 2002, 2013).

2.2 Contextualized Explicit-Reflective Approach for Teaching NOS

The explicit and reflective method for teaching NOS was utilized in this study. This method is based on teaching NOS in a purposive manner, drawing students' attention to certain NOS aspects and being explicit in emphasizing these key concepts through discussions, and providing students opportunities to reflect on their understandings of the NOS by making connections between different topics and activities (Khishfe & Abd-El-Khalick, 2002; Lederman, 2007).

The contextualized explicit-reflective approach was utilized in this study (Clough, 2006). Educators can use different contexts to embed NOS instruction (Mulvey & Bell, 2017). Context used for NOS instruction include historical and contemporary science examples (e.g., Abd-El-Khalick & Lederman, 2000; García-Carmona & Acevedo-Díaz, 2017), inquiry-based activities (e.g., Erumit, Fouad, & Akerson, 2019; Khishfe & Abd-El-Khalick, 2002; Burgin & Sadler, 2016; Ozgelen et al., 2013), and socioscientific issues and/or other science content (Eastwood et al., 2012; Khishfe, 2012b). Our research required preservice teachers to use "science content" and/or historical and contemporary science examples as context when developing NOS storybooks.

While decontextualized-explicit reflective NOS instruction can draw students' attention to certain science aspects, teaching NOS integrated into science content helps students recognize NOS as part of science content instead of seeing it as an addition to science lessons (Akerson et al., 2011). Whether contextualized in a science topic or not, science education researchers discuss the importance of making NOS explicit (Bell et al. 2016; Mulvey & Bell, 2017). To date, the findings of empirical research that compared the decontextualized approach to contextualized approach in NOS instruction has not found a notable difference (e.g., Bell et al., 2011, 2016; Khishfe & Lederman, 2006). With this in mind, we used from decontextualized to minimally, moderately, and highly contextualized NOS activities in our coursework (Mulvey & Bell, 2017). We offered preservice teachers to use either of the two approaches to develop storybooks while preferring contextualized approach.

2.3 Using Children's Literature to Teach NOS

Integrating children's literature into science teaching has become a more common teaching method, and many middle schools integrate science trade books as part of their science programs (Royce & Wiley, 1996). Ford (2006) examined 44 trade books for their representations of science. He found out that most books covered informational texts and covered only certain aspects of science while misrepresenting many aspects of science. Abd-El-Khalick et al. (2017) analyzed high school biology, chemistry, and physics textbooks. They found out that only less than 2.5% of those textbooks strove to represent NOS aspects and did not consistently change across content areas. Similarly, Kelly (2018) analyzed award-winning children's science trade books and found that most books lacked explicitly portraying ideas about NOS. These studies indicate a need for explicit representations of NOS in such books.

In a recent study, Brunner and Abd-El-Khalick (2020) selected some science trade books and modified these books to include explicit representations of three targeted NOS aspects (empirical, creative, and the relationship between observation and inference) and developed a teacher's guide to support elementary teachers' teaching of NOS and their views of targeted NOS aspects. The findings of this study showed that teachers' views and practices of teaching NOS improved after they used the trade books and the teacher's guide. In addition, students' views of NOS were also improved, although not at the same level as the teachers'.

Teachers should recognize the accuracy of the content and wisely choose trade books (Janke & Norton, 1983; Royce & Wiley, 1996; Sackes et al., 2009). Those books should involve accurate and up-to-date information, the writing style should be clear, and the organization should explain the content (Janke & Norton, 1983). Some trade books do not include a teacher's guide to help teachers be prepared for teaching NOS effectively (Abd-El-Khalick et al., 2017). Sackes et al. (2009) reviewed children's science books and found many misconceptions and inaccurate illustrations.

Hansson et al. (2020) explored the use of book talks to teach preschool students about NOS through children's books. The researchers used the term "book talk" to explain how students and the teacher summarized the book and NOS ideas they covered through discussion. Teachers were able to focus on empirical data, scientific knowledge being able to change, characteristics of scientific knowledge, and scientific knowledge has human elements. Researchers found that even preschool students were able to engage in conversations about NOS through children's literature.

Akerson, Avsar Erumit, and Elcan Kaynak (2019) explored incorporating children's literature into a science methods course for early childhood teachers through which the preservice teachers developed their own children's books to teach NOS. Results showed that the preservice teachers refined their conceptions of NOS, and were able to plan, deliver, and reflect on their teaching of NOS; they could design children's books that incorporated NOS aspects accurately and in ways accessible to young children.

Science stories are not only attractive for young learners but also older learners. Kirchhoff (2008), who used stories with her 10th-grade biology students, stated that incorporating stories into science classrooms could turn students from passive learners into active learners who engage in discussions about the content of the stories. She included reading activities that addressed NOS and scientific inquiry through stories about scientists and their discoveries. She also used reading activities as assessment tools and assessed students' understanding of NOS before and after reading stories.

3 Methodology

In this study, we used a basic descriptive qualitative research approach to describe preservice science teachers' knowledge of NOS included in their science storybooks and their enactment of reading these storybooks in their field experience. Merriam and Tisdell (2015) mentioned basic qualitative studies as how people describe, interpret, and make sense of the world. To illustrate how preservice teachers portray their NOS understanding in their storybooks and how students reflect on the NOS storybooks, we conducted an in-depth research study to provide further insight into the use of storybooks in NOS teaching and understanding.

We used qualitative content analysis (Krippendorff, 2018) to analyze the qualitative data of storybooks by identifying accurate and explicit representations of NOS. We also used qualitative analysis of transcribed classroom discussions about five storybooks read by five of the preservice teachers in their field experiences. We provide more detail in the sections below. The following section describes the context and participants in the study, followed by the methods we used to answer our research questions.

3.1 Context and Participants

We collected data from a public university and a public middle school located in the northeast region of Turkey. The participants of this study were 50 middle school science preservice teachers taking nature and the history of science course, and 13 sixth-grade female students who shared in book discussions carried out by these preservice teachers. Preservice teachers were in their third year of a 4-year teacher education program. Of these preservice teachers, 13 were male and 37 were female. All preservice teachers were in their early twenties except one female student pursuing her second undergraduate degree and was in her early thirties.

In the nature and the history of science course, we introduced the history of science from ancient times to the present to deepen preservice teachers' understanding of major scientific inventions and philosophical movements that contributed to the development of scientific knowledge. Along with our discussions about historical and contemporary movements and debates in the history of science, we also supported the lessons with several decontextualized or contextualized NOS activities such as tricky track, draw a scientist and a model (adopted from Chambers (1983) and revised with some additions), a fossil completion activity, a black box activity, young and old lady, the aging president, and cubes activities (Lederman & Abd-El-Khalick, 1998). Each activity focused on at least one aspect of the NOS and varying levels of science content. When we used the young and old lady and aging president activities, for example, we did not discuss any science content. Still, we just discussed the aspect of subjectivity by emphasizing how a person's viewpoints may be different than other people's. Similarly, when we used cubes activity, we did not discuss any science content but focused on NOS aspects such as empirical evidence, observation and inference, and subjectivity. When we used the tricky track activity (Lederman & Abd-El-Khalick, 1998), there was a minimal contextualization of science content, which was the predator and prey relationship, animal tracking, and footprints. The NOS aspects emphasized in the activity were tentativeness, observation and inference, and subjectivity.

The intent of the draw a scientist was to determine the images preservice teachers held about scientists and discuss why many people have stereotypical images about scientists and their lives (Chambers, 1983). We modified this activity and tried to make it more entertaining and mysterious by adding a scenario. This activity involved a scenario that says a scientist and a model were married; one wants to have a child while the other says no. The scenario does not give who is who. This activity asks to draw both the scientist and the model and explain who does not want to have a child with reasons. This activity showed that preservice teachers had stereotypical images of different jobs. Almost all of them drew that the scientist was the man, who was ugly, hardworking, and spent almost his life in the laboratory while the model was the woman, who was beautiful, and cared very much about her appearance. Nearly all of them stated that the model was the one who did not want to have a child because she thought she would not leave time for her beauty after having a child.

Along with such activities, we also used NOS activities that had a high level of science-content contextualization. We embedded NOS aspects of empirical evidence and tentative NOS in an activity about plate tectonics and earthquakes. In addition, we gave some research homework such as selecting a scientist and researching their life and their contribution to science. We had preservice teachers share their findings and then discussed about scientists in terms of their contributions to the development of science, the type of socio-cultural environment in which they lived, and the challenges (if any) they confronted in their lives. In addition to the classroom activities, we examined the national Turkish science education curriculum regarding its NOS inclusion. See Table 1 for the detailed structure and content of the course.

The preservice teachers were not teaching in a field experience class that particular semester; however, we still wanted them to develop lesson plans to use these storybooks. Five of the 50 preservice teachers were the first author's students in the field experience classroom in the following semester. As a follow-up to our primary data, we asked them to read aloud the stories to a middle school science classroom in their field experience at students' weekly book reading lesson. The public middle school was an Islamic Imam Hatip school (Islamic vocational school) where girls and boys were educated in different classrooms. We did not purposely select that school but these preservice teachers were assigned to that particular school for their science field experience. As such, we observed the preservice teachers using their books with students. The school varied in their students' socioeconomic status and academic achievement. Like many vocational schools, the classrooms in that particular school were also separated into boy and girl classes. Because our preservice teachers taught in girls' classrooms, they read their storybooks to a sixth-grade class which consisted of 13 female students. Each preservice teacher read one book each week for 5 weeks.

Nature of science is not a big component in Turkey's national middle school science curriculum (MoNe 2018). There are a few exceptions where we see NOS aspects

Table 1 Timeline of the course content

Week	Content
1	Introduction of scientific knowledge, NOS, scientific literacy
2	Science in ancient times—Mesopotamian science—ancient Egypt and India
3	Science in ancient times—ancient Greek and China, the philosophical movements in science
4	Scientific developments in the modern ages. Comparing roles of scientists in traditional and contemporary understandings. Draw a model and a scientist activity
5	Model use in science—features of scientific models, nature of technology
6	Approaches for teaching NOS-decontextualized NOS activities, cubes activity, young and old woman activity, tricky track activity
7	Approaches for teaching NOS-contextualized NOS activities—teaching NOS in a multidisciplinary approach—black box activity, earth science and NOS activity
8	Mid-Term
9	Adding literacy into account: contextualized NOS teaching—teaching NOS through science storybooks—sharing examples of science storybooks written by preservice science teachers—introduction of final homework
10	Where is NOS in the national science curriculum?: examining science standards and NOS traces in the curriculum. Examining a science lesson plan that emphasizes science content, NOS aspects, and literacy connections
11	Students' presentations—book sharing
12	Students' presentations—book sharing
13	Students' presentations—book sharing
14	Finals week

explicitly addressed in the standards. For example, one standard in the seventh-grade cell unit emphasized how scientific knowledge can change over time. Similarly, one standard in the seventh-grade atom unit also emphasizes tentativeness as it states how theories about atoms have changed over time.

Because NOS is not much addressed in the national science education curriculum that teachers compulsorily follow, teachers rarely attempt to teach NOS in their classrooms. The middle school classroom teacher whom our preservice teachers worked for their field experience also stated that he did not explicitly teach NOS in his classroom. In short, the middle school students whom our preservice teachers read their books to never explicitly learned about NOS. In addition, our preservice teachers could not teach NOS to these students during their field experience as they also followed the standards that the classroom teacher sent weekly. Therefore, they only read the books during a lesson called "book reading hour," a separate lesson from science lessons. Because teachers were not forced to follow the national curriculum or use a standardized plan in these book hour lessons, our preservice teachers read the NOS storybooks in these book reading hours and focused on the science content, and the NOS aspects emphasized in the books.

Nevertheless, we picked the storybooks for them to share that were in line with the sixth-grade topics given in the national curricula. Three preservice teachers read their own stories as the science topics addressed in these three books were in line with the sixth-grade topics. However, two preservice teachers' books were too high in written level for sixth-grade students; therefore, we replaced these two books with books written by two other preservice teachers who provided permission. The science topics of these five books were the shape of the earth, solar system and planets, matter and mixtures, human body, and body systems.

3.2 Data Collection

Data sources included 50 preservice teachers' own written NOS storybooks, and audio recordings of classroom discussions about five of these storybooks read by preservice teachers during their science field experience. Before the study, we gave informed consent forms to preservice teachers and asked for their voluntary participation. Because all preservice teachers volunteered in the study, we did not exclude any storybooks from the analysis. The first author, the instructor of the nature and history of science course, collected data. The class met twice a week for 4 h weekly. See Table 2 above for detailed information about the course content. As their final assignment, each preservice teacher created a science story book to teach about NOS. They also developed a lesson plan in which they integrated their own storybooks as part of the lesson.

We did not provide formal training about how to write a storybook. We wanted preservice teachers to create their own unique books from their creative backgrounds but required them to include NOS. However, the first author translated and shared some sample storybooks written by preservice early childhood teachers who created their book in a science method course (see Akerson, Avsar Erumit, & Elcan Kaynak 2019). Using these books as guidance, the author discussed how to develop a NOS story book that is appropriate for middle schools' age levels. She also discussed what they should not include in the books (e.g., slang, inappropriate image, inaccurate information, etc.). Furthermore, the first author offered guidance to ensure that preservice teachers were on track in developing quality science storybooks. For this purpose, preservice teachers came to the instructor's office hours when they needed and asked for suggestions during the development process of the books.

The criteria for the books were (1) explicitly include at least two NOS aspects; (2) use NOS aspects contextualized in science content (preferable) or use them decontextualized in a fashion to teach the aspects specifically on their own; (3) use characters (popular or created); (5) use illustrations that are in line with the text, the characters, and the age level of students; (6) use technology to design the books; (7) use in-text citation if you use information from outside sources and include references at the end of the book; and (8) share the book in the classroom on the designated date and explain science concepts and the NOS aspects covered in the book. We encouraged them to develop electronic books because storing electronic books was more convenient for the course instructor and the preservice

Table 2 The frequency of accurate representations of NOS aspects

NOS aspects	Frequency and percentage
Observation and Inference	30 books (60%)
Tentativeness	24 books (48%)
Subjectivity	20 books (40%)
Creativity and Imagination	16 books (32%)
Empirical Evidence	16 books (32%)
Empirical Evidence	16 books (32%)

teachers. We informed preservice teachers about the story book assignment at the beginning of the semester and designated a particular date for each preservice teacher to share their books.

The preservice teachers were not teaching in a field experience that semester; however, we still wanted them to develop lesson plans to use these storybooks in the future. The criteria for the lesson plans were as follows: (1) choose a science concept that is the same or aligns with the topic covered in the story book; (2) design a lesson plan using the 5E instructional model (Bybee, 1997; Bybee et al., 2006); (3) use activities to explicitly teach NOS aspects (the same aspects covered in the story book); (4) integrate the story book in the lesson plan (reading and discussing the ideas and NOS aspects covered in the book); (5) include related science standards and NOS objectives. We chose the 5E instructional model for lesson planning as it provides structure for teaching and also allows for explicit-reflective instruction for NOS and science content. The elaboration phase, which allows learners to apply their understanding in a new situation (Bybee et al., 2006), may be an excellent phase to embed NOS if not embedded in previous steps. Also, preservice teachers were familiar with that approach from their previous coursework.

As mentioned before, five preservice teachers among 50 were the first author's students in the field experience classroom in the following semester, in a setting close enough to collect data. As a follow-up to our primary data, we asked these five preservice teachers to read aloud the stories to a middle school science classroom in their field experience at students' weekly book reading hour. We audio-recorded these sessions in which each preservice teacher read their books and held a discussion about each book, specifically focusing on the NOS aspects covered in the book.

Each preservice teacher shared their storybooks in the science methods class. We discussed the minor issues (if any were found) related to the science content or the structure after each presentation. Both the first author as the instructor of the course and peer preservice teachers provided feedback and suggestions about the NOS inclusion and the content for the improvement of the books. Preservice teachers submitted revised versions of the books to a digital classroom platform that we used throughout the semester. All 50 books were prepared using technology such as PowerPoint. One of the books included text and audio with the preservice teacher's voice recorded reading the book.

3.3 Data Analysis

We conducted a content analysis of the storybooks and recorded findings regarding explicit and accurate portrayals of NOS aspects. More specifically, we used deductive content analysis to search for specific episodes in the storybooks where seven NOS aspects were explicitly mentioned (Graneheim et al., 2017; Kyngäs et al., 2020). To increase reliability and validity, the first author conducted the content analysis by revisiting the storybooks multiple times and recording findings regarding explicit and accurate portrayals of NOS aspects into a pre-structured analysis matrix. The first author translated pertinent portions of the books into English and constructed the data table. When the first author completed the coding, the second author cross-checked all the codes in the matrix (Creswell, 2014).

The content analysis categories included (1) the science content covered in the book, (2) the science unit that the topic taught in the national curriculum, (3) the grade level, (4) the book's characters, (5) the scientist characters of the book, and (6) accuracy of representations of the NOS aspects. We utilized Lederman et al. (2002) and Lederman and Lederman (2014) as primary sources to determine the accuracy of NOS aspects included within the books. Lederman and colleagues comprehensively explained aspects of NOS and presented illustrative examples of students' naive and informed views for each aspect. These examples provided insight into how students with naive or informed views thought about the target NOS aspect.

The second round of analysis included the transcription of the classroom discussion held with sixth-grade students about five of these storybooks and selecting dialogue related to NOS aspects covered in the books. Themes within the discussions were sought to determine the types of conversations held in connection with the storybooks. When we transcribed the dialogical data, we used condensed transcription and only transcribed the parts related to NOS aspects while removing unnecessary words from our transcription (Evers, 2011). When sharing examples, we used the exchanges where students explicitly reflected on NOS aspects.

4 Results

The 50 books cover various content areas that include various physical science, life science, and earth science. Forty-seven preservice teachers had NOS aspects contextualized into other science content. Three preservice teachers used decontextualized instruction and solely focused on NOS aspects in their books without connecting to science content. Six preservice teachers targeted either elementary or high school level while the others developed their books and the plans for middle school level (4–8). While 28 preservice teachers preferred to use popular main characters such as worldwide famous movies, cartoons, stories, and fairy tale characters or famous scientists, 22 preservice teachers created their characters in their stories.

Fourteen preservice teachers used scientist characters in their books. Twelve of them used worldwide known scientists, and two used scientist characters that they created in their books. Five of those used scientists as one of the main characters; the rest mentioned scientists and their work somewhere in their books. Famous scientist characters included Charles-Augustin de Coulomb, Newton, Albert Einstein, Robert Hooke, Anton Van Leeuwenhoek, Robert Brown, Gregor Mendel, John Dalton, Joseph John Thompson, Ernest Rutherford, Niels Bohr, and Thomas Alva Edison. One preservice teacher used Canan Karatay, who is a nationwide known Turkish dietician as a scientist character, and one used Al-Biruni (Persian scholar) in her story. Looking at the list of the scientist characters, we see that almost all scientist characters are men and came from Western cultures. Only one preservice teacher used a woman scientist, and another preservice teacher used a non-Western scientist who was a Persian scholar.

In the following section, we report the content analysis of storybooks; explicit and accurate representations of NOS. Representative quotes from the storybooks exemplify these major categories. We also share representational dialogues from book discussion sessions in which five preservice teachers and their students discussed NOS aspects. We picked the dialogue exchange where students explicitly vocalize NOS aspects that are covered in the book.

4.1 Explicit and Accurate Representations of NOS Aspects

The content analysis of the storybooks found that all PSTs except one included at least one NOS aspect explicitly in their books. The results showed that there were no inaccurate representations of NOS. Some NOS aspects are cited more frequently than other aspects. We have presented the frequency and the percentages of the representations of each NOS aspect in Table 2 below. We have provided a representative sample from the books for each aspect.

Observation and Inference Observation and inference was the most frequently cited aspect among all seven aspects of NOS. Thirty books (60%) explicitly and accurately represented this aspect.

> Example: Two children went to a pond with their grandfather where they saw tadpoles. It was the first time they had seen tadpoles, and they made some observations of these organisms. They thought tadpoles were baby fish. After closely observing a tadpole with their magnifiers, they made some inferences about the tadpole and predicted what type of fish it would be. One child said that it was a trout because its color was dark. The other child said it was a carp because it was enormous. Then they took this tadpole from the pond and put it into their water bottle with some pond water. They frequently observed its growth and one day, they found out that it was a frog. The book's characters explained how their inferences evolved and changed as they gathered more evidence and made more observations of the organism. The book represented NOS aspects, including tentativeness, empirical evidence, and observation and inference. In the book, the preservice teacher also talked about metamorphosis and the life cycle of frogs (Storybook, 43).

Tentativeness Tentativeness was second in line in terms of the frequency of aspects used in the storybooks. Twenty-four (48%) books accurately included the aspect of the tentativeness of scientific claims.

> Example: An old couple sells their home-grown organic vegetables in a local farmers market. At the beginning of the story, the old lady complained about decreased crop yields. She did not want to use hormones and pesticides in their products. She did not want to use genetically modified seeds, either, as she thought it could eventually threaten its natural environment and human beings. Later in the story, the old couple searched more about genetic engineering in agriculture and found out that there is more research about genetic engineering that has found several benefits of genetically modified organisms. Then they start to grow their plants with genetic engineering techniques. As time went on, more evidence became available about genetic engineering so that the people [in the book] felt better about its use and safety (Storybook, 13).

Subjectivity Subjectivity was the next commonly used aspect, with 20 preservice teachers (40%) including it explicitly and accurately in their books.

> Example: Nasreddin Hodja—a cultural and humorous icon of Turkey—fell in the middle of a discussion among villagers about the Earth's shape. That is how he decided to invent a time machine and traveled into the past and the future to collect evidence about the shape of the Earth. In the book, Hodja went to different countries

> and met with scientists and talked with them about the Earth's shape. At the end of the book, he was convinced that the Earth was not flat with more empirical evidence. In a part of the book, it said how different scientists could have different subjective views about the same phenomenon based on their experiences, background knowledge, views, and culture from where they came (Storybook, 1).

Creativity and Imagination Sixteen preservice teachers (32%) accurately and explicitly included the role of imagination and creativity in their stories. Below is an example of accurate usage of that aspect.

> Example: Keloglan (bald boy)—a fictional character from Turkish culture—walks with two scientists in a forest where they find a fossil fragment. Two scientists start a discussion about what kind of species the fossil fragment could belong to. They draw the organism that they think it could be on their notebooks, and both have different results. The bald guy asks, "how did you guys come up with different drawings by observing a very tiny fossil?" They explained that they used their background knowledge as well as their creativity and imagination. Here, the bald guy announced that he realized how scientific knowledge is a product of human inference, imagination, and creativity. This part of the book is also similar to a fossil activity we did in the classroom. That shows how this preservice teacher accurately conveyed his understanding and used additions in his own written book (Storybook, 8).

Empirical Evidence Sixteen pre service teachers (32%) used empirical evidence explicitly and accurately in their books.

> Example: Two friends were playing in a park where they observed different plants and animals. They then questioned whether plant and animal cells were different or the same. In their school laboratory, they looked at an onion cell and a human cheek cell under a microscope with the help of their classroom teacher. They drew the cells in their science books and wrote down the features of both cells. At this part of the book, they explained how they made observations of the cells and collected empirical data to answer their scientific question just as all scientists need to collect evidence to develop a scientific knowledge (Storybook, 22).

Social and Cultural Influence The social and cultural aspect of science was included by ten preservice teachers (20%).

> Example: The book's main character is Gregor Mendel's granddaughter who was knowledgeable about his life and scientific work on genetics. In part of the storybook, the PST mentioned how Mendel's work was not appreciated during his life because of various social–cultural factors that included lack of readership of his published work and lack of statistical foundation in the field at that time (Storybook, 23).

Theory and Law Theory and law and the distinction between the two knowledge were the least commonly cited NOS aspect among all aspects. Although we were searching for accurate representations of NOS aspects, we found that only two preservice teachers included the scientific knowledge of theory and/or law in their books; however, these books did not explicitly mention the distinction between these two scientific knowledge and were not examples of accurate representations.

> Example: *Inside Out* movie characters (with their given Turkish names) sit in the dark to watch a movie. One of the characters removed his woolen sweater, where they saw many tiny sparks. In the book, the preservice teacher talked about static electricity and Coulomb's law. However, she did not describe the difference between law and theory (Storybook, 44).

4.2 Book Discussions

Although the national science curriculum of Turkey does not include NOS activities and students did not explicitly learn about NOS in their science classes, they were interested in the NOS books. They were highly engaged in the book discussions. The results of book readings and follow-up discussions showed that middle-school students were explicit and reflective on NOS aspects each of the 5 weeks. Below we share two dialogical exchanges between students and preservice teachers who read the storybook on that particular week. We picked these two dialogical exchanges as exemplary in which students made explicit reflections about NOS aspects.

In our first example, the book read by a preservice teacher was about the solar system and planets (see Appendix for the transcription of the storybook). The preservice teacher personified the planets in the book, and she named each planet as a person in the family. Pluto was the youngest person of the family in the book. Later in the books, the scientists found out in light of new evidence that Pluto was not a planet but a dwarf planet. The book addressed the NOS aspects of tentativeness and observation and inference. After reading the book, the preservice teacher asked what the students understood from the book. Below is the dialogue between her and the students;

> Preservice teacher 1: What did you understand from the book?
> Student 1: We saw that scientists' explanations of things could change over time.
> Preservice teacher: How did you understand this?
> Student 1: Pluto was in the family first, and then, it was found out with some testing that it was not a planet but a dwarf planet. It means that the explanation of science has been changed.
> Preservice teacher 1: Anything else?
> Student 2: I agree! We have seen that Pluto is not a planet any longer, it is a dwarf planet. The explanation of its planetary status has been changed.
> Student 3: What do you mean by dwarf planet?
> Preservice teacher 1: Some features differentiate planets from dwarf planets. Pluto is not meeting all these requirements to be considered as a planet.
> Preservice teacher 1: The explanation of scientific phenomena can change in light of new evidence. We call it tentativeness. How did you like the book?
> The students: We love it! We always want to listen to science topics from storybooks. Can you please read another book next week?

The dialogue above shows us that students mentioned the tentative NOS based on Pluto's planetary status humorously mentioned in the book. These reflections show their quick understanding of the aspect. The last part of the dialogue also shows us students enjoyed listening to a science storybook. They asked the preservice teacher whether or not she would read another book in the upcoming week. Before the preservice teacher read the book, these students did not discuss the NOS aspects with their classroom teacher.

The second week, another preservice teacher read a book about the Earth's shape to the same students (see Appendix for the transcription of the storybook). In the book, the main character, Nasreddin Hodja, found himself in a discussion about the Earth's shape. Some of his neighbors thought the Earth was flat, while others thought it was spherical. Then, he invented a time machine and went to different countries in different times in the past and listened to people share ideas about the Earth's shape. In the book, the preservice teacher mentioned how other people, as well as different scientists, had subjective views about the Earth's shape. An exchange from the follow-up discussion is below:

> Preservice teacher 2: What can you tell me about the book?
> Student: We have seen that some people used to think that the Earth's shape was like a tray. Other people used to believe that the shape of the Earth was like a box. Nasreddin Hodja went to different lands and talked to different people, and eventually, he was convinced with that the Earth's shape was not flat.
> Preservice teacher 2: How did his view change?
> Student 2: The explanations on scientific things changed in time. We see in the story that different people explained the shape of the Earth differently.
> Preservice teacher 2: That is true! We call it subjectivity. What else can you tell me?
> Student 2: We saw that they collected evidence about the sky when they were observing the sky with a telescope.

As seen in the dialogue above, students reflected on the scientists' subjective interpretations of data and mentioned that scientists interpreted scientific knowledge differently. Also, they shared ideas about the empirical evidence aspect as they mentioned how scientists collected data after they started to use telescopes.

The third preservice teacher read her story about homogenous and heterogeneous mixtures. In the story, Chef Smurf was making ayran (a traditional salty yogurt drink) by mixing water, yogurt, and salt. Then, the Grouchy Smurf said "Why are you shaking ayran? I hate people who shake ayran". Then, Chef Smurf explained that the mixture is not homogenous everywhere, although he shook it for a long time. Then Brainy Smurf made some observations and inferred that some mixtures are heterogeneous while others were homogenous. The dialogue below is taken from a follow-up discussion between the preservice teacher and the students;

> Preservice teacher 3: Can you tell me what you learned from the story?
> Student 1: Scientists make observations and then explain what happens. For example, the Smurfs just shook ayran, made observations, and explained that ayran is not the same throughout the mixture. They just found out that ayran was a heterogeneous mixture.

The fourth book was about the kinds of nutrients in food. The book's main character was a child and wanted to learn what kinds of nutrients different foods had. In the story, the child did experiments with the help of his grandpa to find answers to his scientific question. They used foods and different kinds of chemical food indicators (such as Lugol iodine solution) to understand the properties of these foods.

> Preservice teacher 4: What happened in the story?
> Student 1: Emir [the child] did some experiments and made some observations.

Preservice teacher 4: What did he find?
Student 2: He dropped a chemical (Lugol or something) on foods and observed that some turned bluish purple while others did not change colors. Then he explained that foods that had carbohydrates altered the color. Then, he used the same method in different foods to see if other foods turned out to be the same color. Finally, he used his findings as evidence to explain the properties of the foods. The foods that turned to a bluish purple color had carbohydrates.
Student 2: What is a Lugol solution?
Preservice teacher: Lugol iodine solution is a chemical and used in laboratories as a food indicator.

Students reflected that scientists made some observations and experiments and collected evidence to explain the properties of foods. They mentioned the aspects of empirical evidence and observation and inference.

The fifth book was about the history of microscopes and cell biology. In the story, the preservice teacher mentioned how models of cells had been changed in light of new evidence after the invention of more advanced microscopes. Although the follow-up discussion did not last as long as previous weeks, students still made reflections on the aspect of tentativeness.

Preservice teacher 5: What happened in the story?
Student: We see the tentativeness—same as previous weeks—I mean the Pluto book.
Preservice teacher 4: What do you mean by tentativeness?
Student: The explanation of scientific things can change in time, including the description of cells.
Preservice teacher 4: That is true. The explanation of scientific phenomena can change over time. That is called tentativeness. Anything else?…

The above dialogue showed us that students could transfer their understanding of some aspects that they learned from previous stories when reflecting on a new storybook. For example, one student said, "we see tentativeness in that story just like we have seen that aspect in the Pluto book".

4.3 Discussion

Current science education reform efforts focus on scientific literacy as one central principle of science education and consider an understanding of NOS and an understanding of science content as critical for developing scientific literacy (such as NGSS 2013). In this study, we examined Turkish preservice middle-school science teachers' own written science storybooks in terms of their NOS coverage as well as middle-school students' reflections of five of the books.

Looking at the NOS aspects represented in the storybooks, the frequencies among the different aspects within the books are uneven. Observation and inference and tentativeness were the most commonly used two aspects among all seven aspects of NOS in the storybooks. Other aspects of NOS were included less frequently in the storybooks. For example, the social and cultural aspect of NOS is included in only ten storybooks. This result is in line with the findings of previous research. Akerson et al. (2011) also found that students could more readily comprehend some aspects of the NOS, such as observation and inference, tentativeness, empirical evidence, and creativity, while some aspects of science were less accessible and less comprehensible, including the social and cultural NOS aspect. This result is similar across different age groups, and even preservice and in-service teachers can find learning and teaching some aspects of NOS more complex than other aspects. One teacher from the study of Leden et al. (2015) stated that she was not good at teaching social and cultural aspects because that particular teacher considers this aspect as more challenging to teach.

Looking back to the scientist characters used in the storybooks, we see that all except one scientist character are men, and all except two scientist characters chosen for the books came from western culture. This result is similar to previous studies that analyzed science trade books in terms of characteristics of their scientist characters or the text describing the scientist character (Ford, 2006). We tried to tear away stereotypical scientist images from preservice teachers' minds throughout the semester with our discussions and activities. Yet they continued using western culture male scientists more often. These engrained images cannot be completely removed in one semester. As described in the methodology section, we used the modified version of the draw-a-scientist activity (Chambers, 1983) at the beginning of the semester.

Although we could not assess middle school students' long-term understandings of NOS and science concepts covered in the storybooks, we can still infer that storybooks can support students' understandings of complex science topics and NOS aspects when read and discussed interactively. As Lederman and Lederman (2004) discussed, almost any science topic can be restructured to address NOS aspects without wandering away from the subject matter that is intended to be taught. Our findings showed that preservice teachers successfully embedded NOS aspects into a wide range of science content. For example, students in our study mentioned how Pluto lost its planetary status and became a dwarf planet during the discussion session of the storybook (see Appendix for the transcription of the storybook). This finding is in line with the results of Emmons et al. (2018), as the scholars found using narrative picture storybooks effective in developing young children's comprehension of adaptation. This finding suggests that repeated use of similar materials across different science topics may deepen students' understanding of NOS.

Science storybooks can be used as media to encourage students to reflect on their NOS understandings and support explicit-reflective NOS instruction. Previous studies showed that explicit and reflective approach was practical for improving students' conceptions of NOS (Akerson, Elcan Kaynak, & Avsar Erumit, 2019; Bell et al., 2016; Eymur, 2019; Khishfe, 2008, 2012a; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007). Akerson, Elcan Kaynak, and Avsar Erumit (2019) provide research-based suggestions on how to use explicit-reflective NOS instruction in science classrooms. Embedding NOS into existing science curricula by addressing NOS within science content and children's literacy were two effective strategies addressed in that study.

Designing and using children's books can be a tool to provide explicit reflective NOS instruction. Using storybooks improves students' understanding of NOS and can improve teachers' views of these NOS aspects. Our findings suggest that developing storybooks and sharing them in the classroom reinforced preservice teachers' understanding of NOS aspects. They accurately and explicitly portrayed aspects of NOS in their storybooks. In a recent study, Brunner and Abd-El-Khalick (2020) found that teachers improved their views of particular NOS aspects after using these aspects in trade books as part of their science instruction.

4.4 Limitations

Although this study had promising results, we are still aware of its limitations. First, we were able to use only five of the books with middle school students. As a result, we could not gather information about the long-term effect of storybooks' on the development of students' NOS understandings. Further research in this area would benefit from a design in which the classroom teacher can use storybooks to support NOS instruction for a more extended period.

The second limitation of the study was that the preservice teachers read books to middle school students isolated from their regular science teaching. Because there were particular standards that the preservice teachers needed to cover weekly and the topics addressed in storybooks were not prepared as in line with the standards, the preservice teachers read the books in a separate book reading classroom. Students would benefit more from the books if the storybooks were read as part of the science lesson.

The third limitation of the study was that the first author of the paper taught the course and analyzed the course data. Because data collected were in Turkish, the first author translated related data parts into English and shared them with the second author for crosschecking. Each of the 50 books was about 5–20 pages long; it was hard to translate all details in the books into English. Therefore, the first author translated the parts that included statements about NOS for the crosschecking done by the second author. So while the second author was not able to read the entire books, she was able to crosscheck and validate the analysis.

4.5 Concluding Remarks and Implications for Future Research

The findings of this study have meaningful implications for future research. This study shows how supporting materials can be developed that target multiple science domains simultaneously and can be used across different content areas. Even such minor interventions can increase students' interest in learning science, promote their understanding of NOS, and raise their awareness of how scientists practice science. Further longitudinal research in this area would be beneficial in examining the effect of such interventions on students' understanding of NOS over time.

This study will contribute to the literature about literacy and science and using children's books for the NOS instruction and calls for further long-term studies about whether or not using these books helps children develop their NOS conceptions. This study shows that middle school students can hold explicit reflective conversations about NOS facilitated through a children's book focused on NOS. Also, preservice teachers can facilitate NOS discussion with middle-school students using children's books, even when it is not much included in the science curriculum. For example, in a science method course, the professor can implement an assignment where preservice teachers develop a resource to teach their future students about NOS. Preservice teachers can implement that resource to facilitate their students' discussions about NOS aspects.

This study took place in Turkey, where NOS instruction does not explicitly involve in the national curriculum. Therefore, practical suggestions provided in this study are meaningful for science teachers on how to include NOS in their instruction. However, teachers can incorporate more NOS and supporting NOS instructional materials into their teaching if the curriculum explicitly included NOS standards. Science educators, therefore, should watchfully consider how to include NOS in science curricula (Cheung, 2020). It is essential to have NOS standards in the curriculum along with content standards in Turkey, where teachers compulsorily follow the national science curriculum.

Appendix

Story 1

Hapless Pluto

Once upon a time, there were many planets in space, and some of these planets were legendary for their strong family ties. One of them was the solar system that consisted of the Sun, which was the mother of nine planets. Each of the children of mother Sun had distinctive features. For example, Jupiter was the largest among the siblings, while Saturn has been known with its beautiful ringlets, and Uranus has been known with its icy materials that contained methane. Neptune was the most antisocial and the coldest child of the Sun and therefore it was the most distant to its mother. Mars was blushing with anger and therefore its color was red. Uranus was the mischievous child and was always rotating on its sides. Mercury, who loved his mother the most, was always in close proximity to his mother, so his temperature was high. The most intelligent and resourceful of them was planet Earth. The smallest and the quietest was Pluto. One day everybody was bored and decided to play a game. However, the game ended with an unfortunate accident… Pluto was injured from the accident. The mother Sun took his son, Pluto to the doctor. The doctor made some testing including a DNA testing. The results of the DNA test showed that Pluto was not the child of the Sun. The Sun and other planets were shocked with the results and read the doctor's report. The report presented some empirical evidence and said Pluto was a dwarf planet… Pluto lost his planetary status and became a dwarf planet. That shows us our explanation of scientific knowledge can change in light of new evidence and interpretation of findings from further observations.

Story 2

Time Machine of Nasreddin Hodja

Once upon a time, Nasreddin Hodja was going to the wheat mill with his Donkey, named Karakacan. He met with two villagers on the way. One of the men was digging a hole while the other was filling the opened hole with a shovel. Nasreddin Hodja observed them for a while but he could not understand what they were doing. He burst into laughter and said, what are you guys doing here? Then Sir Hasan said, "Hodja! God sent us you. You came here to find an answer to our question". Sir Ahmet said, "Hodja, you are the one who can find a Nasreddin Hodja," "hey you guys, just tell me what the problem is".

Sir Ahmet, "Hodja, Hasan claims that 'if the world is a sphere, then I would go to the other side of the world using a tunnel that is dug from one side to the other side of the World'".

Nasreddin Hodja, "I think it is a spectacular idea. Then, why are you mad with that? Why are you filling the opened hole?".

Hasan, "Come on, Hodja! How do we know that the Earth is spherical? What if the world is flat? If it is flat, then we all fall into the hole and can't come back. If it were spherical, wouldn't those who were below the earth fall upside down?".

Nasreddin Hodja was confused. Things that both Hasan and Ahmet said all made sense to him. He could not decide which one was right.

The Hodja could not think of an answer and took Karakacan and continued on his way. The men shouted! "Hodja! Where are you going? You have not found an answer, yet!".

The Hodja shouted back, "Masters, let's meet at the same place two days from now. I need to catch prayer time" [Nasreddin Hodja never says he does not know the answer].

He started off on his way with many questions in his mind. He started to talk to his donkey, "Karakacan, what shape do you think the Earth is? How would we find an answer to this question". Suddenly, he had an idea. He thought he would invent a time machine and travel in time to meet people and listen to what they thought about it. Nasreddin Hodja worked hard and finally he invented a time machine and was ready for the journey. Will Hodja ever go without Karakacan? No way! He took the donkey and pressed the button on the machine.

First they went to ancient Egypt. Nasreddin Hodja and Karakacan started wandering around Egypt. When they saw a man, Hodja could not resist and asked, "Do you know that the Earth is spherical?" The Egyptian man was mad and he said, "What are you talking about, man, the Earth is like a box and the sky is like a lid of the box". Other people around them were looking at confusedly. A man [Nasreddin Hodja] in a big turban cap on a donkey! Does such thing ever happen in the middle of the desert? Hodja was scared of people and said, "Karakacan, run, run, press that button". Once again, they started traveling in time… Then, they went to ancient India and talked to people they met. Each of them said a different thing about the shape of the Earth. The widely accepted view was that the earth was carried on an elephant which had turtles under its feet and turtles swam in an endless sea.

Nasreddin Hodja was completely mixed up. They pressed the button and went a little further in time. This time, Hodja and Karakacan met with Christopher Columbus [Italian explorer], who was preparing to sail with three ships. Hodja asked, "Where are you heading to?" Columbus said, "If the Earth is spherical, we would return to where we start our trip"… Nasreddin Hodja decided to travel to the future when technology would be more advanced and scientific studies are carried out about earth and space. The he pressed the button and went to NASA where they met with scientists and saw lots of picture of Earth taken from space. These pictures showed that the Earth was spherical.

Then, they pressed the button and came back in time when they lived. Nasreddin Hodja made it to meet the two men on time. Sir Hasan and Sir Ahmet waited for the response.

Nasreddin Hoca: Masters, evidence is needed to explain a scientific phenomenon. The shape of the Earth thought to be flat or disk in the past. The explanation of this scientific phenomenon changed over time with the advancement of technology and in light of new evidence. We know that the Earth is spherical based on the current evidence we have.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

References

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

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but... *Journal of Science Teacher Education, 12*(3), 215–233.

Abd-El-Khalick, F. (2012). Nature of science in science education: Toward a coherent framework for synergistic research and development. In B. J. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (Vol. 2, pp. 1041–1060). Springer.

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

Akerson, V. L., Buck, G. A., Donnelly, L. A., Nargund-Joshi, V., & Weiland, I. S. (2011). The importance of teaching and learning nature of science in the early childhood years. *Journal of Science Education and Technology, 20*(5), 537–549.

Akerson, V., Nargund-Joshi, V., Weiland, I., Pongsanon, K., & Avsar, B. (2014). What third-grade students of differing ability levels learn about nature of science after a year of instruction. *International Journal of Science Education, 36*(2), 244–276.

Akerson, V. L., Avsar Erumit, B., & Elcan Kaynak, N. (2019). Teaching nature of science through children's literature: An early childhood preservice teacher study. *International Journal of Science Education, 41*(18), 2765–2787.

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., Elcan Kaynak, N., & Avsar Erumit, B. (2019). Development of Third Graders' Identities as" Persons Who Understand Nature of Science" through a Gravity Unit. *International Journal of Research in Education and Science, 5*(2), 450–456.

Akgun, S., & Kaya, E. (2020). How do university students perceive the nature of science? *Science & Education, 29*(2), 299–330. https://doi.org/10.1007/s11191-020-00105-x

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

Bell, R. L. (2009). Teaching the nature of science: Three critical questions. *Best Practices in Science Education, 22*, 1–6.

Bell, R. L., Matkins, J. J., & Gansneder, B. M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414–436.

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. https://doi.org/10.1080/09500693.2016.1151960

Brunner, J. L., & Abd-El-Khalick, F. (2017). Representations of nature of science in U.S. elementary science trade books. In C. V. McDonald & F. Abd-El-Khalick (Eds.), *Representations of nature of science in school science textbooks a global perspective* (pp. 135–151). New York: Routledge.

Brunner, J. L., & Abd-El-Khalick, F. (2020). Improving nature of science instruction in elementary classes with modified science trade books and educative curriculum materials. *Journal of Research in Science Teaching, 57*(2), 154–183.

Burgin, S. R., & Sadler, T. D. (2016). Learning nature of science concepts through a research apprenticeship program: A comparative study of three approaches. *Journal of Research in Science Teaching, 53*(1), 31–59.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices*. Portsmouth, NH: Heineman.

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness* (pp. 88–98). BSCS, 5.

Casteel, C. P., & Isom, B. A. (1994). Reciprocal processes in science and literacy learning. *The Reading Teacher, 47*(7), 538–545.

Chambers, D. W. (1983). Stereotypic images of the scientist: The draw-a-scientist test. *Science Education, 67*(2), 255–265. https://doi.org/10.1002/sce.3730670213

Cheung, K. K. C. (2020). Exploring the inclusion of nature of science in biology curriculum and high-stakes assessments in Hong Kong. *Science & Education, 29*(3), 491–512.

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.
Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage.
DeBoer, G. E. (1991). A history of ideas in science education. New York: Teachers College Press.
Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education, 34*(15), 2289–2315. https://doi.org/10.1080/09500693.2012.667582
Emmons, N., Lees, K., & Kelemen, D. (2018). Young children's near and far transfer of the basic theory of natural selection: An analogical storybook intervention. *Journal of Research in Science Teaching, 55*(3), 321–347.
Erduran, S., & Dagher, Z.R. (2014). *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories*. Springer. https://doi.org/10.1007/978-94-017-9057-4_1
Erduran, S., Dagher, Z. R., & McDonald, C. V. (2019). Contributions of the family resemblance approach to nature of science in science education. *Science & Education, 28*(3), 311–328.
Erumit, B. A., Fouad, K. E., & Akerson, V. L. (2019). How Do Learner-Directed Scientific Investigations Influence Students' Questioning and Their Nature of Science Conceptions?. *International Journal of Education in Mathematics, Science and Technology, 7*(1), 20–31.
Evers, Jeanine C. (2011). From the Past into the Future. How Technological Developments Change Our Ways of Data Collection, Transcription and Analysis [94 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 12*(1). https://doi.org/10.17169/fqs-12.1.1636
Eymur, G. (2019). The influence of the explicit nature of science instruction embedded in the argument-driven inquiry method in chemistry laboratories on high school students' conceptions about the nature of science. *Chemistry Education Research and Practice, 20*(1), 17–29.
Ford, D. J. (2006). Representations of science within children's trade books. *Journal of Research in Science Teaching, 43*(2), 214–235.
García-Carmona, A., & Acevedo-Díaz, J. A. (2017). Understanding the nature of science through a critical and reflective analysis of the controversy between Pasteur and Liebig on fermentation. *Science & Education, 26*(1), 65–91.
Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In A. Berry , J. Loughran, & P. Friedrichsen (Eds.), *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 38–52). essay, New York: Routledge.
Graneheim, U. H., Lindgren, B. M., & Lundman, B. (2017). Methodological challenges in qualitative content analysis: A discussion paper. *Nurse Education Today, 56*, 29–34.
Hansson, L., Leden, L., & Thulin, S. (2020). Book talks as an approach to nature of science teaching in early childhood education. *International Journal of Science Education, 42*(12), 2095–2111. https://doi.org/10.1080/09500693.2020.1812011
Hapgood, S., & Palincsar, A. S. (2006). Where literacy and science intersect. *Educational Leadership, 64*(4), 56–60.
Hodson, D. (2009). *Teaching and learning about science: Language, theories, methods, history, traditions and values*. Brill Sense Publishers.
Irzik, G., & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education, 20*(7), 591–607.
Janke, D., & Norton, D. (1983). Science trades in the classroom: Good tools for teachers. *Science and Children, 20*(6), 46–48.
Kaya, E., & Erduran, S. (2016). From FRA to RFN, or how the family resemblance approach can be transformed for science curriculum analysis on nature of science. *Science & Education, 25*(9–10), 1115–1133.
Kelly, L. B. (2018). An analysis of award-winning science trade books for children: Who are the scientists, and what is science? *Journal of Research in Science Teaching, 55*(8), 1188–1210.
Khishfe, R. (2008). The development of seventh graders' views of nature of science. *Journal of Research in Science Teaching: THe Official Journal of the National Association for Research in Science Teaching, 45*(4), 470–496.
Khishfe, R. (2012a). Relationship between nature of science understandings and argumentation skills: A role for counterargument and contextual factors. *Journal of Research in Science Teaching, 49*(4), 489–514.
Khishfe, R. (2012b). Nature of science and decision-making. *International Journal of Science Education, 34*(1), 67–100.

Khishfe, R., & Abd-El-Khalick, F. (2002). The 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: THe Official Journal of the National Association for Research in Science Teaching, 43*(4), 395–418.

Khishfe, R., & Lederman, N. (2007). Relationship between instructional context and views of nature of science. *International Journal of Science Education, 29*(8), 939–961.

Krajcik, J. S., & Sutherland, L. M. (2010). Supporting students in developing literacy in science. *Science, 328*(5977), 456–459.

Krippendorff, K. (2018). Content analysis: An introduction to its methodology (4th ed.). Thousand Oaks: SAGE.

Kyngäs, H., Kääriäinen, M., & Elo, S. (2020). The trustworthiness of content analysis. In H. Kyngäs, K. Mikkonen, & M. Kääriäinen (Eds.), *The application of content analysis in nursing science research* (pp. 41–48). Springer.

Leden, L., Hansson, L., Redfors, A., & Ideland, M. (2015). Teachers' ways of talking about nature of science and its teaching. *Science & Education, 24*(9–10), 1141–1172.

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

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831–880). Lawrence Erlbaum Associates Inc.

Lederman, N. G. (2019). Contextualizing the relationship between nature of scientific knowledge and scientific inquiry. *Science & Education, 28*, 249–267. https://doi.org/10.1007/s11191-019-00030-8

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 83–126). Kluwer Academic.

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

Lederman, N., & Lederman, J. (2004). Revising instruction to teach nature of science: Modifying activities to enhance students' understanding of science, *The Science Teacher, 71*(9), 36–39.

Lederman, N. G., & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education, Volume II* (pp. 614–634). Routledge, New York.

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics Science and Technology, 1*(3), 138–147.

Merriam, S. B., and Tisdell, E. (2015). *Qualitative Research: A Guide to Design and Implementation* (4th Ed.). San Francisco: John Wiley & Sons.

MoNE – Turkish Ministry of National Education [Milli Eğitim Bakanligi] (2018). Science Education Curriculum for Grades 4–8. Retrieved August 18, 2021, from http://mufredat.meb.gov.tr/Dosyalar/201812312311937-FEN%20B%C4%B0L%C4%B0MLER%C4%B0%20%C3%96%C4%9ERET%C4%B0M%20PROGRAMI2018.pdf

Monhardt, R., & Monhardt, L. (2000). Children's literature and environmental issues: Heart over mind? *Reading Horizons: A Journal of Literacy and Language Arts, 40*(3), 175–184.

Moser, S. (1994). Using storybooks to teach science themes. *Reading Horizons, 35*(2), 138–150.

Mulvey, B. K., & Bell, R. L. (2017). Making learning last: Teachers' long-term retention of improved nature of science conceptions and instructional rationales. *International Journal of Science Education, 39*(1), 62–85.

Mutonyi, H. (2016). Stories, proverbs, and anecdotes as scaffolds for learning science concepts. *Journal of Research in Science Teaching, 53*(6), 943–971.

National Science Teachers Association. (2000). NSTA position statement: The nature of science. Retrieved August 18, 2021, from, www.nsta.org/about/positions/natureofscience.aspx.

NGSS Lead States. (2013). *Next generation science standards: For states by states*. National Academies Press.

Osborne, J. (2002). Science without literacy: A ship without a sail? *Cambridge Journal of Education, 32*(2), 203–218.

Ozgelen, S., Yilmaz-Tuzun, O., & Hanuscin, D. L. (2013). Exploring the development of preservice science teachers' views on the nature of science in inquiry-based laboratory instruction. *Research in Science Education, 43*(4), 1551–1570.

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science, 328*(5977), 459–463.

Pringle, R. M., & Lamme, L. L. (2005). Using picture storybooks to support young children's science learning. *Reading Horizons: A Journal of Literacy and Language Arts, 46*(1), 1–15.

Robbins, C., & Ehri, L. C. (1994). Reading storybooks to kindergartners helps them learn new vocabulary words. *Journal of Educational Psychology, 86*(1), 54.

Royce, C. A., & Wiley, D. A. (1996). Children's literature and the teaching of science: Possibilities and cautions. *The Clearing House, 70*(1), 18–20.

Sackes, M., Trundle, K. C., & Flevares, L. M. (2009). Using children's literature to teach standard-based science concepts in early years. *Early Childhood Education Journal, 36*(5), 415–422.

Shi, X. (2021). Using explicit teaching of philosophy to promote understanding of the nature of science. *Science & Education, 30*(2), 409–440.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Yacoubian, H. A. (2021). Students' views of nature of science. *Sci & Educ, 30*, 381–408. https://doi.org/10.1007/s11191-020-00179-7

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.