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Of Course Scientists Haven't Seen Dinosaurs on the Beach: Turkish Kindergartners' Developing Understanding of the Nature of Science Through Explicit–Reflective Instruction

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Abstract

Although the importance of nature of science (NOS) instruction for learners as young as kindergartners is emphasised in a great number of documents and studies, very little research has been conducted in early childhood contexts. Thus, researchers are still not able to see a comprehensive picture of young children's understandings of NOS. The purpose of this qualitative study is to investigate kindergartners' developmental ability to comprehend tenets of NOS. Using an explicit–reflective approach and activities designed to develop their understandings of NOS, we instructed eight kindergartners for 10 days over the course of a month to document changes in their thinking. To this end, they were interviewed individually using Young Children's Views of Science before and after instruction. The results indicate that generally, the kindergartners had an inadequate understanding of NOS before instruction but had developed it by the end of instruction. Each child's understanding of the individual aspects of NOS developed to different degrees, creative NOS improving most substantially. This study corroborates that kindergartners are not developmentally constrained to develop informed NOS understandings. On the contrary, they are able to develop an informed understanding of NOS that can be improved by the implementation of explicit–reflective instruction.

Keywords Early childhood education · Nature of science · Explicit–reflective instruction

Introduction

Rapid development in science and technology make the development of scientific literacy a necessity for all individuals. Accordingly, the goal of science education is stated as scientific literacy for all students from kindergarten through grade 12 in US science education reform documents (National Research Council [NRC] 1996; Next Generation Science Standards [NGSS] 2013). In a similar manner, the importance of scientific literacy has been reflected in Turkish elementary science education programs. The Turkish Ministry of National Education (MoNE) defines the goal of science education as creating scientifically literate individuals in all science education programs to date (MoNE 2005, 2013, 2017).

Scientific literacy involves an awareness that science, mathematics, and technology are independent human enterprises; an understanding of key scientific concepts, principles and inquiry skills; the use of scientific knowledge and scientific ways of thinking for individual and social purposes; and understanding nature of science (NOS) (American Association of Advancement of Science [AAAS] 1989; NRC 1996). Scientific literacy expands and deepens over a lifetime, not just during the years of education. However, it is known that a person's development of scientific literacy as an adult is related to the attitudes and values established toward science in the early years (NRC 1996). For this reason, it can be said that the early years are critically important for educating scientifically literate individuals.

One of the essential components of scientific literacy is to develop an adequate understanding of NOS (Klopfer 1969; NRC 1996). To create a scientifically literate society, NOS

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instruction accessible to all students needs to take place starting in the early grades (AAAS 1990; Abd-El-Khalick et al. 1998; NRC 1996; Türkmen and Yalçın 2001). Accordingly, the latest US reform document Next Generation Science Standards (NGSS), which defines a fundamental goal for K-12 science education as creating science literate individuals who understand the nature of scientific knowledge, addresses the importance of teaching and learning NOS by incorporating it into their dimensions of the standards (NGSS 2013).

NOS refers to the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman 1992). For K-12 learners, NOS is their conceptualisations of what science is and who uses it, how and by whom scientific knowledge is constructed, and where the children as learners place themselves within the community of producers and users of science (Walls 2009). In their NOS position statement, the National Science Teachers Association (2000) asserts that anyone involved in teaching and learning science should have an accurate view of NOS. They highlight several premises of understanding NOS that are important in the context of this study: scientific knowledge is simultaneously reliable and tentative; naturalistic explanations must be supported by empirical evidence and be testable against natural world; a scientific approach includes observation, rational argument, inference, sckepticism, peer review, and replicability of work; creativity is a vital component in the development of scientific knowledge; there is a relationship between observations and inferences; and science is to some extent subjective.

In NGSS, eight understandings of NOS and their intersection with science and engineering practices, disciplinary core ideas, and crosscutting concepts are presented according to grade level (K-2, 3–5, middle school, and high school). Appropriate grade-level outcomes are also presented in detail, and the importance of NOS instruction and how to include NOS in school programs is specifically emphasised (NGSS 2013).

A remarkable amount of research addressing the teaching and learning of NOS is found in the literature. These studies provide researchers an in-depth understanding of the issues, such as both students' and teachers' conceptions of NOS and how these conceptions can be improved (Lederman 1992). However, young learners' (especially pre-K children's) understandings of NOS are not well represented in the research. Although the necessity and importance of NOS instruction for learners as young as kindergartners is emphasised in a great number of documents and studies (AAAS 1990; Abd-El-Khalick et al. 1998; Akerson et al. 2011; Bell and Clair 2015; NRC 1996; NGSS 2013; Türkmen and Yalçın 2001), very few of NOS studies have been conducted in early childhood contexts (Akerson et al. 2011; Akerson and Donnelly 2010; Akerson and Volrich 2006; Quigley et al. 2011). The scarcity of research on young learners is confirmed by a study conducted by Walls (2016), who examined 112 peer-reviewed NOS studies originating and conducted in the US from 1967 to 2013. Just 4 of the studies' participants were identified as elementary students. Similarly, Bell and St. Clair (2015) point out the shortage of research into young learners' conceptions of NOS, particularly those of pre-K children; they emphasise the need for additional research to determine which aspects are most appropriate for young learners and to validate a learning progression for teaching NOS to students of all grade levels.

In a Turkish context, the need for research on NOS in early childhood is even clearer. To date, no aspects of NOS have been mentioned in any of the Turkish MoNE Early Childhood Education Programs (MoNE 1994, 2002, 2006, 2013). Furthermore, young children (pre-K, K-2 students) are the most neglected group; for instance, no research investigating kindergartners' understandings of NOS has been found in Turkish literature, but there is a great number of studies related to teachers' and elementary, high school, and university students' views of NOS (Çakıcı and Bayır 2012; Doğan and Abd-El-Khalick 2008; Doğan and Özcan 2010; Erdoğan et al. 2006; Kaya 2012; Küçük 2006). However, although they paint an incomplete picture (Bell and Clair 2015), there are a few studies exploring young children's views of NOS in international literature (Akerson et al. 2011; Akerson and Donnelly 2010; Quigley et al. 2011). These studies emphasise that young learners can improve their understandings of NOS. Similarly, Akerson et al. (2011) overemphasised that it is never too early to begin teaching NOS and that young children are not developmentally constrained in attaining more informed NOS views. In light of the studies revealing the improvements in NOS understandings of young children, and owing to the shortage in national and the international literature, the aim of the study is to investigate kindergartners' understandings of targeted aspects of NOS (tentative NOS, empirical NOS, subjective NOS, creative NOS, and observation and inference) and the changes in their understandings after participating in an explicit–reflective NOS instruction in a Turkish context.

Conceptual Framework

There are three instructional approaches to improving learners' understanding of NOS: historical, implicit, and explicit–reflective. An explicit–reflective approach suggests the importance of teaching aspects of NOS with an intentional focus, rather than as a by-product of engagement in instruction. The term 'explicit' does not refer to didactic teaching strategies here. Instead, it emphasises that NOS understandings are cognitive learning outcomes and should therefore be intentionally targeted during instruction (Khisfhe and Abd-El-Khalick 2002). Much research has emphasised that explicit–reflective instruction is the most effective in improving learners' understandings of NOS (Abd-El-Khalick and Lederman 2000; Akerson and Donnelly 2010; Akerson and Volrich 2006; Khishfe and Lederman 2006; Khishfe and Abd-El-Khalick 2002). Therefore, we used explicit–reflective instruction in this study as an approach to teaching targeted aspects of NOS, tentative NOS, creative and imaginative NOS, empirically-based NOS, subjective NOS, and the distinction between observation and inference.

Theoretical Framework

Science learning in early years is very important for a future science-literate society, and science education considers early childhood as a period for building the conceptual foundation that young people will use to construct advanced understandings of scientific concepts and NOS (Bell and Clair 2015). In contrast, an outdated idea presumes that children have limited scientific capacity and are not developmentally ready for science. Metz (1995, 2004, 2011) asserted that children are more capable scientists than the developmental assumptions imply; they are able, for example, to observe, collect data, and make inferences to learn. She also affirmed that their capacity cannot be characterised by stage alone and highlights the importance of appropriate instruction and scaffolding for children to reach their full potential.

Metz (1995) also emphasised that neither Piagetian nor non-Piagetian developmental literature supports the developmental constraints on children's science instruction, noting that Piaget's later work on children's development reveals their potential. Despite the evidence, science educators have preserved the idea that young children are developmentally limited (Metz 1995, 2011).

This underestimation of children's capacity for learning science seems to have watered down the MoNE Early Childhood Education Program in Turkey (MoNE 2013). The program includes science process skills as acquisitions but does not incorporate any aspects of NOS or other developmentally appropriate science acquisition for children. Thus, children's capacity to learn science is oversimplified, and the question of what is developmentally appropriate for children remains unanswered. The existing study is guided by the views of scientists of cognition and development who assert that young children are ready for science instruction; they are capable scientists and able, for example, to observe, collect data, and make inferences to learn.

Methodology

Qualitative research is an umbrella term that covers many other terms (Bogdan and Biklen 2007; Merriam 2009), among which is the basic research methodology that guided this research. In basic qualitative research, the purpose is to understand how people make sense of their lives and their experience and what meaning they attribute to their experiences (Merriam 2009). In this research, we tried to understand how children make sense of their experience by observing what understanding a group of kindergartners had obtained through NOS instruction.

Participants

The participants in this study were 8 children attending a public primary school's kindergarten in a city located in midwestern Turkey. To determine the participants, we used criterion sampling, which is a purposeful sampling method. The first criterion to determine the participants was group size, as it affects the child–adult ratio. It is known that higher quality education has been associated with a smaller child–adult ratio. The US National Association for the Education of Young Children (NAEYC) suggests a ratio of maximum 10:1 for 5- and 6-year-olds. Unfortunately, according to MoNE's statistics for 2015–2016 academic year, there are approximately 23 children in a public kindergarten and one teacher for this large group (MoNE 2016). Since it had been planned that the class would be taught by the first author, we had only one teacher for NOS instruction; this meant that the ratio would have been 23:1. For this reason, we tried to find a group that was not too crowded. The teacher of the group was the second criterion by which the participants were determined: He or she must not have taken any course related to NOS or have participated in a previous scientific project about science education and NOS in early childhood in which the two authors were researchers. Therefore, a public kindergarten class with 13 officially enrolled children and a teacher with the abovementioned characteristics was chosen for the study. Before the study began, all of the children's parents were informed about the aim and content of the study. All parents signed a consent form allowing their children to participate in the study. However, 3 children dropped out of the class and the study started with 10 children. During the study, 2 children moved to another city. By the end of the research 8 children remained. Therefore, these 8 children were the participants of the entire study. Of these children, 4 were female and 4 were male. Their age range was 66–75 months. All of the children lived within the school zone and were from a neighbourhood of low socioeconomic status. The school had two kindergarten classes, and the study was conducted during the afternoon kindergarten class.

Interviewer and Instructor

During the study, Author 1 interviewed the children and taught the kindergarten class. She has a BA in elementary science education and took courses related to NOS as part of her undergraduate education. She also has an MA in Early Childhood Education. This study is a part of her master's thesis. She has 1.5 years of science teaching experience in grades 3–8 and 6 years of research experience in early childhood science education. Before the study started, Author 1 was present in the kindergarten and played with the children during their playtime for 3 weeks in order for everyone to get used to each other.

Intervention

The intervention started after individual pre-interviews with the children, using Young Children's Views of Science (YCVOS) (Lederman and Lederman 2010). The whole intervention took place in the kindergarten classroom except the day that we went on a fieldtrip to a science centre. The intervention took 10 days over the course of a month, and during the intervention using an explicit–reflective approach nine activities related to NOS and one field trip were carried out. Five NOS aspects—tentative NOS, creative and imaginative NOS, empirically-based NOS, subjective NOS, and the distinction between observation and inference—were focused on. See Table 1 for an overview of the activities and NOS emphases by week. After the intervention, post-interviews using YCVOS were conducted with each child individually.

Data Sources and Collection

To determine the children's understandings of NOS, we used Young Children's Views of Science (YCVOS) as pre- and post-interviews. Developed by Lederman and Lederman (2010), YCVOS is an open-ended instrument designed for very young students, who have limited reading and writing abilities. The authors and three other researchers translated YCVOS into Turkish. One protocol was formed after reviewing the Turkish translations of YCVOS, and we submitted it to experts in the field of early childhood education for their views. After receiving this feedback, we completed all necessary editing. Next, we created pilot interviews with three kindergartners attending the morning session to check whether YCVOS was efficient or not. In light of the pilot interviews, we removed the first section of Part II because paper helicopters in that section distracted the children's attention and they wandered off topic. This part also prolonged the interview, and the children generally talked about the helicopters and became bored with the subsequent parts of the interview.

Lederman and Lederman (2010) recommend interviewing a small number of students at a time. However, because the children were very young, we felt that they could be easily impressed by their friends and repeat or copy each other. Therefore, to determine each child's own NOS views, we interviewed one at a time before and after the instruction, as Akerson and Donnelly (2010) suggested. Interviews were undertaken in a quiet room provided by the school administration. Prior to the interview, we reminded the children that there were no right or wrong answers to the questions and that they could answer however they wanted. We paid careful attention not to lead the children toward a particular response. For this reason, we did not respond to the children's answers at the time. Interviews lasted approximately

Table 1 Overview of NOS activities in the intervention

Activity number	Activity	Emphasised NOS aspects
1	Draw a scientist[a]	What is science? What does a scientist do?
2	Trip to a science centre	What is science? What does a scientist do?
3	Tricky tracks[a]	Creative and imaginative, tentative NOS, observation versus inference
4	Cubes activity[a]	Creative and imaginative, tentative, empirical NOS, observation versus inference
5	Fossil activity[a]	Creative and imaginative, tentative, subjective, empirical NOS, observation versus inference
6	Reading activity—*What do you do with a tail like this?* (Jenkins and Page 2009)	Creative and imaginative, subjective NOS, observation versus inference
7	Finger prints[a]	Empirical NOS, tentativeness
8	Cartoon activity[a]	Creative and imaginative, tentative, empirical NOS

[a]The activities (Lederman and Abd-El-Khalick 1998) were retrieved from the webpage of Project ICAN which was a project run by Norman and Judith Lederman and activities adapted for kindergartners by authors. For detailed information about activities visit https://science.iit.edu/mathematics-science-education/resources/project-ican/teachers/activities/cube-activity

25–30 min. All individual interviews were audiotaped and transcribed verbatim for analysis.

Data Analysis

We took an interpretive approach to analysing the data derived from pre- and post-interviews, and we focused on the meanings participants attributed to aspects of NOS. To reveal the children's understandings of targeted NOS aspects, data were analysed by two researchers independently (Author 1 and another researcher who has an MA in science education and 7 years of experience teaching different grades). The analyses of the two researchers were compared to ensure reliability. There was 90% agreement between the two independent analyses. The disagreement between the analyses was discussed, and following a review of the analysis, the differences were eliminated and consensus was obtained.

Some of the questions on YCVOS place more emphasis on the assessment of a single target NOS aspect, but generally they assess more than one. For instance, Questions 2a and 2b in Part II focus more on the participants' understandings of the distinction between observation and inference than the other questions. However, participants can also express their understandings about this aspect in response to other questions. For this reason, we used a holistic approach, as recommended by Khishfe and Abd-El-Khalick (2002). We analysed the data without assuming a one-to-one correspondence between a question and a target aspect of NOS. Khishfe and Abd-El-Khalick (2002) argue that there are two major advantages of this approach. First, it gives participants the opportunity to demonstrate their conceptions of NOS in a variety of contexts rather than interpret their understandings from a narrow perspective aiming to obtained the desired responses to certain questions. Secondly, the researchers can check the consistency of participants' responses across the questionnaire items to understand whether the responses are a representation of meaningful understanding of NOS or just a repetition of key terms.

The analysis suggested by Lederman and Lederman (2010) consists in categorising YCVOS responses as 'naïve' or 'informed' and in distinguishing whether the response is consistent and addresses most parts of NOS or not. At the start, we decided to divide responses into two categories; however, during the analysis, we realised that some children had not responded, some responses were irrelevant because they had completely strayed from the subject, and some were inadequate. We decided to categorise these responses under different codes. Moreover, there were some differences in the responses categorised as informed. For this reason, we decided to add an 'adequate' category. Thus, to conduct an in-depth evaluation and analysis, we categorised the children's responses as 'no response', 'irrelevant response', 'inadequate', 'adequate', and 'informed'. If a child did not respond to a question, it was coded as no response, and a child's response that was not related to the question was coded as an irrelevant response. A response that was not consistent with any part of a NOS aspect was coded as inadequate. On the other hand, a response that was consistent with NOS aspects was coded as adequate and a response that was consistent with NOS aspects and involving an extra explanation, example, or both was coded as informed.

Results

In this section, we provide the children's pre- and post-instruction conceptions of NOS. We also draw a general picture of the changes in the children's understandings of NOS. Quotations from the children's responses are presented to illustrate both their initial understandings and the changes in it. Pseudonyms are used instead of the children's names. The overall changes in the children's understandings of targeted NOS aspects are given in Tables 2 and 3.

Children's Pre-instruction Understandings of NOS

In this section, we describe the kindergartners' understandings of targeted NOS aspects before the instruction.

Tentative NOS

Based on pre-interview results, it can be said that children generally had an inadequate understandings of tentative NOS. One child did not respond, and one gave an irrelevant answer. The remaining 6 of 8 children had an inadequate understanding of tentative NOS and indicated that scientists' ideas do not change over time. For instance, Kaya stated, 'They do not change because life is always the same'. Nur said, 'They do not change their ideas because one thing happens in the world. It is impossible to change'. Another child, Efe, also believed that scientists do not change their ideas and supported his belief with an example. He stated, 'For example, scientists are investigating the Earth. The earth is blue. Later it cannot be yellow'. To sum up, prior to instruction, none of the children believed that scientists would ever change their ideas.

Empirical NOS

Before the instruction, one child did not respond to the related interview questions, and one of the children gave an irrelevant answer. Three of the 8 children had an inadequate understanding of empirical NOS. For example, Kaya explained how scientists know that dinosaurs have lived before as 'Scientists know when a dinosaur will be born

Table 2 Children's understandings of emphasised NOS aspects before and after the instruction

Pseudonyms of children	Emphasised NOS aspects									
	Tentativeness		Subjectivity		Empirical		Observation/inference		Creativity	
	Before instruction	After instruction	Before instruction	After instruction	Before instruction	After instruction	Before instruction	After instruction	Before instruction	After instruction
Kaya	Inadequate	Adequate	Inadequate	Adequate	Inadequate	Inadequate	No response	No response	Inadequate	Adequate
Nur	Inadequate	Informed	Inadequate	No response	Adequate	Informed	Adequate	Informed	Inadequate	Informed
Ata	Inadequate	Inadequate	No response	No response	Inadequate	Inadequate	Inadequate	No response	Inadequate	No response
Efe	Inadequate	Adequate	Inadequate	Inadequate	Adequate	Informed	Adequate	Adequate	Adequate	Informed
Nihal	No response	No response	Irrelevant response	Irrelevant response	Irrelevant response	Irrelevant response	Irrelevant response	Irrelevant response	No response	Irrelevant response
Asya	Inadequate	Informed	Inadequate	Informed	Adequate	Informed	Inadequate	Informed	Inadequate	Informed
Sercan	Irrelevant response	Irrelevant response	Irrelevant response	No response	Inadequate	Inadequate	Inadequate	Adequate	Inadequate	Adequate
Ecenaz	Inadequate	Inadequate	No response	Inadequate	No response	Inadequate	Irrelevant response	Adequate	Inadequate	Inadequate

Table 3 Changes in children's understandings of emphasised NOS aspects before and after the instruction

NOS aspect	Before instruction					After instruction					Reverted	Stayed same	Improved
	No response	Irrelevant response	Inadequate	Adequate	Informed	No response	Irrelevant response	Inadequate	Adequate	Informed			
Tentativeness	1	1	6	0	0	1	1	2	2	2	–	+4	+4
Subjectivity	2	2	4	0	0	3	1	2	1	1	–	+6	+2
Empirical	1	1	3	3	0	0	1	4	0	3	–	+5	+3
Observation/inference	1	2	3	1	0	2	1	0	3	2	–	+4	+4
Creativity	1	0	6	1	0	1	1	1	2	3	–	+3	+5

and die'. Another child, Sercan, noted, 'Scientists know that dinosaurs lived because they are so smart'. A third child, Ata, described science as mixing something and revealing new colours. Three children, Asya, Nur, and Efe, had an adequate understanding of empirical NOS. Efe stated, 'Scientists know that dinosaurs lived. They searched for dinosaurs and they found bones'. Asya and Nur also said that scientists found dinosaurs' bones, but they did not explain and support their answers. These responses imply that although they did not explicitly express that science is empirically based, the children were aware of scientists using fossilised bones as evidence of dinosaurs' existence.

Subjective NOS

Pre-instruction, 4 children had an inadequate understanding of subjective NOS, 2 children gave irrelevant responses, and 2 children did not respond. The interviewer asked about the reasoning behind scientists' different ideas about the extinction of dinosaurs. One of the children, Nur, who had an inadequate understanding of subjective NOS, said, 'They can think differently. It is normal. Because everybody's answer must be different'. At first, this seemed to be an adequate understanding; however, during the interview, Nur explained her thought. She mentioned that during activities, their teacher encourages them to speak by saying, 'Everybody can respond differently; do not repeat each other'. Consequently, when the interviewer asked her why scientists think differently about the extinction of dinosaurs, she remembered her teacher. None of the children provided a response indicating subjective NOS, for example, that scientists could have different prior knowledge or interpret data differently.

Observation and Inference

During the pre-interview, 1 child did not respond to related questions, and 2 of the children gave irrelevant responses. Three of the children had an inadequate understanding of observation and inferences. To reveal the children's views, the interviewer asked them how people who predict the weather on TV use science. For instance, Sercan, whose understanding was inadequate, said 'They look at the weather prediction book'. Another child, Asya, said, 'Maybe they search on the internet'. Prior to instruction, 2 children demonstrated an adequate understanding of observation and inferences: While they did not use the exact words, their responses indicated their inadequate understanding of both concepts. For example, Efe said, 'They know from the stars. Or they see the sky is good. Then they go to a documentary (he implies a weather forecast programs) and say that tomorrow it will be sunny'. Similarly, Nur stated, 'They watch the clouds up to where they can see with their eyes. So they can say the weather forecast. Otherwise how can they? They watch which direction the clouds face'. These responses are interpreted by the researchers as evidence of the children's adequate understandings of observation and inference.

Creative NOS

The interviewer asked the children whether scientists use their imagination and creativity while they are working. Pre-instruction, one child did not respond to the related questions, and 6 children revealed an inadequate understanding of creative NOS, thinking that scientists are not creative and do not use their imagination. For instance, Kaya, who had an inadequate understanding of creative NOS, said, 'Scientists are not creative, but they see dreams'. One child's understanding (Efe's) was categorised as adequate: When asked whether scientists use their imagination and creativity while they are working, Efe replied that they do not; however, his responses in a different part of the interview, given below, contradicted this view and indicated that Efe's understanding of creative NOS was adequate.

> Interviewer (I): What do scientists think about how dinosaurs looked?
> Efe (E): They are not too aggressive and they are not too wild. They are middle sized.
> I: How do they think so?
> E: Because they have not seen them.
> I: You say they have not seen dinosaurs, and they describe them. How?
> E: They draw on their imagination as they did not see.
> I: How can they say what they look like?
> E: Because they see the other animals, and the only animal they have not seen is the dinosaurs.

Children's Post-instruction Understandings of NOS

As mentioned in the "Methodology" section, to track the changes in the children's understandings of NOS, we conducted individual interviews after the instruction. In this section, we describe the kindergartners' understandings of targeted NOS aspects after the instruction.

Tentative NOS

Post-instruction, one child did not respond to relevant questions, and one child's response was categorised as irrelevant. Two children's understandings were categorised as inadequate: they mentioned that scientific knowledge would not change over time. Otherwise, there was an improvement in some children's understandings of tentative NOS: 2 children improved from inadequate to adequate, and one of these children, Kaya, whose understanding of tentative NOS was adequate, answered, 'Scientists search for everything. For example, the dwarf planet. Scientists removed it from the planet list. It became a dwarf planet', when the interviewer asked him what scientists do. Kaya's explanations are interpreted as evidence of his adequate understanding of tentative NOS.

Two of the children, Asya and Nur, had an informed understandings of tentative NOS. They both noted that science and scientific knowledge are changeable, and they supported their ideas with examples related to the activities completed during the instruction.

The conversation between Asya and the Interviewer is below.

Interviewer (I): Do you think scientists change their ideas over time?
Asya (A): Yes.
I: What can be changed?
A: Mmm ... For example, our fingerprints.
I: Our fingerprints? How?
A: There were different types of fingerprints.
I: Yes.
A: One of them was arch. (She was drawing it on the board simultaneously.)
I: Yes, it is. Wow, you drew it.
A: One of them was loop. How was it? I can't remember.
I: Ok. I will draw it for you.
A: The other one was ... Mmm?
I: Whorl ... Arch, loop, and whorl.
A: Like this. (She was drawing the fingerprints.)
I: Yes, but how these can be changed?
A: They can change. For example, one type can be heart-shaped.
I: How it can be?
A: Scientists must look at new born babies' fingers. If their fingerprints are heart-shaped, then it can be. Or their fingerprints are like a tree, then tree-type fingerprints arise.
I: Do you know any scientific knowledge that has changed over time?
A: Mmm …
I: Think about it. I explained something about the planets during our activities.
A: Yes, they say Pluto is no longer a planet, it is a dwarf.
The other child, Nur, explained that scientific knowledge can change over time in light of new questions and studies. The conversation between Nur and the Interviewer is below.
Interviewer (I): Do you think scientific knowledge changes over time?
N (Nur): It does.
I: Do you know of any knowledge that has changed?
N: I cannot remember now.
I: Why does scientific knowledge change?
N: Because new questions come.
I: Could you explain a bit more?
N: For example, they predict something. For example, they liken something to something. After doing more research, they understand that it is not the thing they predict, it is another thing. They changed their minds.
I: You are saying that after doing research, they changed their minds?
N: Yes.

To sum up, post-instruction, 4 out of 8 children showed an improvement in their ideas about tentative NOS.

Empirical NOS

Post-instruction, 1 child whose response had been categorised as irrelevant prior to instruction remained the same. The understanding of four of the children remained categorised as inadequate: when asked how scientists know what dinosaurs looked like, they answered, 'Scientists saw the dinosaurs', or 'They saw them on the internet'. These statements illustrate their inadequate understanding of empirical NOS.

Three of the children, Nur, Efe, and Asya, who had an adequate understandings of empirical NOS prior to instruction, had improved their understandings after the intervention. They clearly explained that scientists found the dinosaurs' bones, which allowed them some idea of how dinosaurs looked. The following conversations between the interviewer and the children represents their informed understandings of empirical NOS.

Interviewer (I): No one has ever seen the dinosaurs and there are no dinosaurs around anymore. How do the scientists know they lived?
E (Efe): Because they investigated their bones. They put the bones into their drawers. Later they put the bones together and sent them to museums. That's why everybody can see the dinosaurs.
Interviewer (I): What does it mean—'scientist'?
Nur (N): A scientist is a normal person like us. But they investigate things that we don't know.
I: What do they do?
N: They investigate various things. They discovered that dinosaurs lived before. They understood this by looking at their bones, fossils. Of course they haven't seen the dinosaurs on the beach ... (She is laughing.)
Interviewer (I): No one has ever seen the dinosaurs and there are no dinosaurs around anymore. How do scientists know what the dinosaurs looked like?
Asya (A): Because they found the fossils and they put together the fossils. They also made their robot (she implies a model) for us.

As can be seen from the children's responses, they were aware that scientists used fossils as evidence of the existence of dinosaurs.

Subjective NOS

After the instruction, 3 children did not respond to the relevant question about subjective NOS. One response was irrelevant and two were inadequate. There was one adequate and one informed response; in contrast, all of the pre-instruction responses were either irrelevant or inadequate.

To learn more about the children's understandings of subjective NOS, the interviewer asked about the reason for scientists' different ideas regarding the extinction of dinosaurs. Kaya's explanation, which demonstrated an adequate understanding of subjective NOS, is given below.

> Interviewer (I): Scientists have different ideas about the extinction of the dinosaurs. Why do you think they have different ideas?
> Kaya (K): Because it doesn't have to be the same.
> I: Why?
> K: If they think the same everything in the world would be the same.
> These explanations from Kaya were interpreted as implying that scientists can reach different results. Though he did not say this directly, his last sentence is interpreted as showing that different ideas are necessary for development and innovation.
> Asya, the only child whose understanding was informed after the instruction, explained the reason for scientists' different ideas about the extinction of dinosaurs as follows:
> Interviewer (I): … Why do you think they have different ideas?
> Asya (A): Because they both know different things.

Asya's clear explanation represents her informed understanding of subjective NOS.

Observation and Inference

The children's understandings of observation and inference improved somewhat. After instruction, 2 children did not respond, and one child's response was irrelevant. Three children had an adequate, 2 children an informed understanding of observation and inference.

The following conversation between the interviewer and Ecenaz represents her adequate understanding of observation and inference:

> Interviewer (I): Do you know what observation is? Inference?
> Ecenaz (E): We inferred. We looked at the teddy bear, we listened to it, we smelt and touched it.
> I: So, what does that mean?
> E: So, we said that this is a teddy bear.

Ecenaz did not articulate the relationship between observation and inference, but her responses represent her awareness of the concepts. Thus, her understanding was categorised as adequate.

Nur and Asya clearly explained the relationship between observation and inference by providing examples, as seen below:

> Interviewer (I): How do scientists know that dinosaurs lived before?
> Nur (N): From their fossils. They looked at the fossils and asked which animal had this fossil. They made an inference. They said these fossils belong to a big animal.
> I: OK. Another question. Do you know what a weather forecast is?
> N: Yes. I can say how they do it. They look at clouds, which direction they go, and they make an inference. They predict the weather.
> Interviewer (I): What does it mean—'scientist'?
> Asya (A): Intelligent person.
> I: What do they do?
> A: They investigate. They gave medicine to lab rats to understand whether it is poisonous or not. They make observations.
> I: What do they do after observation?
> A: They make inferences.

These explanations of Nur and Asya represent their informed understandings of observation and inferences.

Creative NOS

After the instruction, 1 child did not respond to the relevant question, 1 child's response was irrelevant, and 1 was inadequate. Ecenaz, whose response was categorised as inadequate, mentioned that scientists use their imagination while they are sleeping.

There were improvements in 5 children: 3 children's understandings of creative NOS were informed, and 2 were adequate. Kaya and Sercan, whose responses were categorised as adequate, stated that scientists use their imagination and creativity while they are making discoveries, but they did not support their views with examples.

On the other hand, the 3 children with an informed understanding of creative NOS noted that scientists use their imagination and creativity, and these thoughts were supported through examples. The conversations below reveal the children's understandings of creative NOS:

Interviewer (I): Do scientists use their imagination and creativity?
Efe (E): Yes.
I: How?
E: They think and make a prediction. For example, they found the dinosaurs' bones. They think, which animal's bones are these? And they use their imagination while thinking.
Interviewer (I): Do scientists use their imagination and creativity?
Nur (N): Yes.
I: Could you give me an example?
N: For example, they think about dinosaurs, how they look. They think and make inferences.
I: Where they use their imagination and creativity?
N: While they think they use them.

From these conversations, it is clear that the children's understandings of creative NOS have improved and that they recognise the creativity and imagination in science.

Discussion

The purpose of this research was to investigate kindergartners' understandings of targeted aspects of NOS (tentative NOS, empirical NOS, subjective NOS, creative NOS, and observation and inference). The results show that, the children generally had an inadequate understandings of NOS prior to the explicit–reflective NOS instruction but displayed a general improvement afterwards. This provides evidence that children, even at the kindergarten level, are developmentally ready to improve their conceptions of NOS. This result is supported by other studies (Akerson et al. 2011; Akerson and Donnelly 2010; Akerson and Volrich 2006, Quigley et al. 2011). Akerson et al. assert that there is no reason to delay NOS instruction until children are developmentally ready; it should begin when science instruction begins. We also believe that children are not constrained in their ability to develop an understanding of NOS. On the contrary, because the early years are considered as a time for building the conceptual foundations that children use later in life of NOS (Bell and St. Clair 2015), we wish to point out that waiting until later grades to teach NOS could constrain their understanding.

According to our findings, it is not possible to say that all aspects of NOS are equally accessible to children, as has been found in other studies (Akerson et al. 2011; Akerson and Donnelly 2010; Quigley et al. 2011). When the improvement in the children's understandings of NOS was examined, it was observed that children's understanding of each aspect improved at different levels (see Tables 2, 3). The results show that the children best developed their understanding of creative and imaginative NOS. Other studies with young children also reveal that creative and imaginative NOS was the most accessible to young children (Akerson et al. 2011; Akerson and Donnelly 2010). Post-instruction, three of the children had an informed understanding, two an adequate understanding of this aspect. In total, 5 of the 8 children showed improvement. The role of observation and inference was also found to be relatively easily accessible: Post-instruction, two of the children had an informed, three an adequate understanding of this aspect. In total, 4 children improved their understandings of observation and inference, since one of the adequate answers was the same as it had been pre-instruction. Also tentative NOS seemed to be an easy aspect. Post-instruction 4 of 8 children showed improvement in their understandings of tentative NOS. Although all aspects were accessible to the children, empirical NOS seemed to be more difficult to access than creative NOS, tentative NOS and observation and inference, but easier than subjective NOS. Post-instruction, only one child had an informed understanding and one an adequate understanding of subjective NOS. Subjective NOS also seemed to be difficult for children in other studies (Akerson et al. 2011; Akerson and Donnelly 2010).

In this study, it was not possible to reveal the exact reason for the difference in the accessibility of these aspects. We believe that for young children, while some aspects of NOS are easier to grasp than others, this does not mean that they are unable to understand all aspects of NOS. Although some aspects are more difficult, children are able to improve their understandings of them, which indicates a potential that should be considered by educators. Educators should keep in mind that children's understanding of science can be improved through scaffolding and appropriate instructional methods (Metz 2004).

The results of this study also clearly reveal the different levels of improvement in the children's understanding after instruction. Pre-instruction, the children's understandings of NOS were generally inadequate; there was no defined difference between them. Post-instruction, there was a difference among the children's improvements. Two children had not improved their understandings. One child showed an improvement in one aspect; another child showed an improvement in two, two children in three, one child in four, and one child in all aspects. It is not possible to explain at this time why two of the children did not improve their understandings. In light of the improvements in the other children's understandings, however, we believe that kindergartners are developmentally ready to develop informed views of NOS. Perhaps they need more time to improve their understandings, or they need other types of activities.

Parallel to other studies conducted with children (Akerson et al. 2011; Akerson and Donnelly 2010; Quigley et al. 2011), we found that explicit–reflective instruction is an effective approach to improving these kindergartners' understandings of NOS. However, we are not able to say whether contextualised or decontextualised explicit–reflective NOS instruction is a more effective strategy because we used a combination of both.

In conclusion, this study corroborates that even at the kindergarten level, children are able to improve their NOS understandings through appropriate instruction; they are not developmentally constrained in understanding NOS. If the children had not been developmentally ready, they would not have improved their understandings.

Recommendations

In accordance with our findings, we suggest that children as young as kindergartners are able to develop an informed NOS understanding. However, they do not naturally improve their understandings. It is important to have them experience as early as possible educational practices designed to improve NOS understandings. This depends on the early childhood educators' understanding of NOS, their knowledge of how to plan NOS instruction, and their motivation to teach NOS. However, studies show that early childhood teachers hold inadequate views of NOS without appropriate instruction (Akerson et al. 2008, 2010; Kaya 2012). Therefore, to develop children's understandings of NOS, we need to take action, targeting the improvement of teachers' understandings of NOS. Coursework on understanding and teaching NOS should be part of all teacher education programs, including early childhood teacher education programs, to provide teachers with adequate knowledge to plan and conduct activities related to NOS.

In this study, the intervention took 10 days over the course of a month. We recommend that researchers plan longer intervention periods in future studies and track the development of the children's understandings over a longer period of time. There is also a gap in the literature relating to young children's (especially pre-K children's) understanding of NOS. Very few studies have been conducted with young children, and we are still not able to see a complete picture of their understanding of NOS. Further research is needed on questions such as how children can improve their understanding in the most effective way, how out-of-school time or informal settings can be used to improve NOS understanding, and how families can be integrated into NOS education.

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Compliance with Ethical Standards

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

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