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Explicit-Reflective Teaching of the Nature of Science for Primary School Students[1]

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Abstract

This study aimed to investigate the effect of a teaching material designed to teach the nature of science to 4th-grade students. For the research, a teaching material was designed, which reflects the tentative, inferential, imaginative, and creative aspects of the nature of science. It was implemented for a total of eight primary school 4th grade students and lasted for two-course hours. Firstly, a preliminary interview was conducted with them. Immediately after the teaching, they were interviewed for the last time. The data were collected through the nature of a science student interview form developed by Khishfe and Abd-El-Khalick (2002) and consisting of a total of six questions. Each student's pre and post-nature of science profiles on three aspects were created and compared. It was determined that the naive views about the tentative, inferential, creative, and imaginative nature of science were observed in the pre-interviews and varied greatly in the post-interviews in a short time. Students who initially believed that scientific knowledge was impeccable and that scientists were 100% sure almost completely abandoned these naive views. We wonder if the change will be permanent and this should be tested with follow-up studies and also how the short time teaching will reflect their daily lives.

Keywords: Teaching the Nature of Science, Primary School Students, Science Education.

1 This study was presented at the 11th National Science and Mathematics Education Congress held at Cukurova University

Introduction

It is well known that the main goal of 21st-century science education is to raise scientifically literate individuals (Bybee, 1985; National Research Council, 1996). Therefore as in many other countries, the main goal of the science curriculum in Turkey has been announced as educating all students as science and technology literate (Ministry of National Education, 2018). One of the many components of scientific literacy is known as the nature of science as a unifying and critical factor (Holbrook & Rannikmae, 2007; Kucuk, 2006). Although the debate about the definition of the nature of science continues among philosophers, sociologists, and historians of science, there is still consensus on the well-known components of the nature of science (NOS) for students. These elements that students from preschool to high school should know about are the tentative nature of science, its inferential nature, imagination, and creative nature, and also others (Lederman, 2007). Kucuk (2006) stated that a student who knows the nature of science understands science, scientific methods, the products resulting from these methods, and the methods encountered in daily life; participates in discussions and decision-making processes on scientific problems; understands the norms of the scientific society and can learn the science subject area more effectively. The decisions made in the institutional and individual fields are largely based on scientific data, it is important to know the NOS for these decisions to be correct. In addition, it is known that primary school students' images of scientists are largely stereotyped (Kucuk & Bag, 2012). There may be a strong correlation between the students' naive views on the NOS and images of scientists, which should probably be tested.

The nature of science can be defined as all the values and beliefs that exist in the development of scientific knowledge. It is still being discussed how to teach science and the nature of science to children, starting from early childhood, to include the values and beliefs in question. Some teaching methods that serve this purpose are put forward and research is continuing about which one gives better results (Khishfe & Abd-El-Khalick, 2002). In the early days, the NOS could be taught implicitly to children and therefore no extra effort was needed. Accordingly, it was deemed sufficient for children to be explicitly exposed to scientific studies, that is, to experience scientific research directly to learn about the NOS. Although some significant gains were observed in some components of the NOS, the continuation of the problem in terms of others encouraged subject field experts to look for new ways. The historical approach, which includes teaching how scientific knowledge (for example, the atomic model) has progressed in the historical process, has been emphasized. The success achieved with this approach has not been satisfactory. There is a consensus that, as a last resort, teaching the nature of science in an explicit reflective way raises the bar (Khishfe & Abd-El-Khalick, 2002; Kucuk & Cepni, 2015). In other words, the NOS should be taught directly, not as a by-product, just as in teaching scientific subjects and concepts. It has been revealed that many activities that serve this purpose have been designed (see Lederman & Abd-El-Khalick, 1998) and have given successful results in many studies all around the world (Khishfe & Abd-El-Khalick, 2002; Kucuk, 2006).

Even with a small examination, it is revealed that middle, high school, and higher education students are taken as the target group in the mentioned research (Dogan & Abd-El-Khalick, 2008; Kucuk, 2008). Although primary school students are mostly excluded from the scope, it is revealed that primary school teachers and primary student teachers' views on the NOS are frequently studied (Abell & Smith, 1994; Lunn, 2002; Murcia & Schibeci, 1999). There were elements in the conceptions of the NOS articulated by these groups which were not in accord with modern views. In this context, the materials in the intervention studies are also designed to serve the relevant target audience. However, the nature of science needs to be taught to students starting from early childhood. For example, the lack of materials for teaching it to primary school students is immediately apparent. It is also concluded that regardless of the learning level, the concepts of the students at the preschool, primary, secondary, high school, and even university levels about the NOS are still naive or transitional. For this reason, it is an important need to develop a teaching material structured at the primary school level and measure its success of it. It is also a necessity to give priority to the NOS teaching materials that can be applied economically in all aspects of new studies.

This study aimed to investigate the effect of a teaching material designed to teach the nature of science to 4th-grade students. To reveal the magnitude of this effect, the difference between the student's views on the NOS at the beginning and after the teaching was measured and compared.

Method

This research is an interpretive study as it focused on the meanings that the students attributed to the nature of science as in some other studies examining students' views on the nature of science (see DiBenedetto, 2015; Kucuk, 2006). The development of students' views about the NOS is analyzed qualitatively in the current research, it can be considered a qualitative study. The study is an interpretive one in nature because it focused on the meanings that the participants attributed to the different elements of the NOS (Lecompte & Preissle, 1993). The research was completed in three stages. Firstly, the views of eight primary students in the study group, in which the second researcher was the official classroom teacher, about the NOS were measured and coded through interviews. Secondly, the teaching material designed for the group was applied. Finally, students' final views on the NOS were re-measured through interviews and coded. In this way, it has been demonstrated to what extent the material in question can improve students' views on the NOS.

The research sample

The sample of the study consisted of eight students attending the 4th grade in a village primary school located in the Cayeli district of Rize in Turkey in the second term of the academic year. Three of them are girls and the others are boys. In this study, students were assigned to four research groups consisting of male and female students. The second researcher reported that these students' experiences with science and scientists are quite limited to the visuals and explanations in the textbook.

Data collection

An interview form created by the researchers was used to evaluate the students' views on the NOS. In this form, six questions are measuring the three dimensions of the nature of science that are tentative, the difference between observation and inference, and the creative and imaginative nature of science. These questions were taken from the nature of the science student questionnaire and simplified in a way that primary school students can easily understand (Khishfe & Abd-El-Khalick, 2002). The interviews with each student and conducted by the second researcher with the permission of the student's parents outside of the class hours before teaching and in the classroom were completed in an average of 30 minutes and were transcribed.

Teaching Process of the NOS

For the research, a teaching material called 'Little Detectives' aimed at changing and improving primary school students' views on the NOS was designed. This material was designed for a special course called 'teaching the nature of scientific knowledge, which the second researcher took in her master's program and was also given by the first researcher. This material development process was completed in a total of seven weeks. In this activity, a last-minute traffic accident news was shared as an audio recording while students watched a video about scientists' lives. In line with the curiosity awakened in the students, they were asked to work on their own and focus on a researchable question about why and how the accident happened. Now, the second researcher gave a few examples, referring to the fact that scientists also started their scientific studies with researchable questions. When the questions were ready and also written on a worksheet, they were divided into groups of four. They were told to consider what data they needed and to request it to be able to answer the questions. During this activity, necessary precautions were taken to prevent the groups from being influenced by each other. During this process, the requested data were given to them via color cards. They were asked to write down each data they received and their explanations about this data on the worksheet. This process aimed for each group of students to produce an explanation based on the data they have and to enrich their explanations continuously. Now, the second researcher referred to the fact that scientists also collect data by observing to find answers to their questions and make inferences by combining them appropriately. In this process, they were also warned many times that their observations and inferences must be based on data. In this event, it has been emphasized many times that they do a little scientific investigation and work like scientists while recording the data and deciding which data to combine and how. In this way, each group worked together and used their data to create the perfect explanation for the cause of the accident. It was shared that they could use their imagination and creativity while doing this. Now, the second researcher referred to the fact that scientists use their imagination and creativity while making inferences using data. Finally, the groups shared their defensible explanation of how much data they had collected and how much of it they had used with others. In this way, possible differences in the data the groups used and the way they combined them were revealed. The activity ended by sharing the statement by the second researcher that "the more data there is, the more detailed explanation can be made and the explanations will not be correct no matter how much data there is".

Data Analysis

The group of eight students' profiles of the NOS was created based on the semi-structured interviews conducted with them. Many studies, which aimed to detect both students' and teachers' NOS understandings, employed this method (Khishfe & Abd-El-Khalick, 2002) (Kucuk & Cepni, 2015). The coding rule for categorizing the participants' views of NOS was built on the perspective that the student's views have a constant change (Khishfe & Lederman, 2003). The student's views of NOS have been categorized in three ways: naïve, transitional, and informed. Before explaining this analytical framework, we need to mention that multiple elements of NOS were explained in more than one questionnaire item. The tentative nature of science is explained based on the student's answers given to the item about the change of scientific knowledge, the item about atoms, and the item about the dinosaurs; the first, second, and third items. To categorize the participants' all views about the tentative nature of science as informed, they were asked to provide evidence that they have informed views in their answers given to all items. If they did not provide enough views for the three items about the NOS, the view held them was categorized as naive. If they provided some views on some items but not others, the views were categorized as transitional. This categorization method was also used in a study conducted by Khishfe, 2004).

Reliability of Data Analysis

A special study was given to establish the reliability of the pre-and post profiles of the participants regarding the NOS. Both pre-and post-interview data on the NOS were coded by both researchers, and a limited number of possible contradictions were fully resolved in a small meeting. Similarly, the validity was established by quoting directly from the students' views, which were used as evidence in the creation of the aforementioned profiles.

Results

Each of the students was identified with a code name that represents them, and their views at the beginning and end of the implementation on the three elements of the nature of the science targeted by the teaching activity were classified using one of the categories— naïve, transitional, and informed—and presented in Table 1 and 2. Table 1 below includes the initial profiles of students about the NOS based on the interview data.

Table 1

Initial profiles of students about the nature of science

Group	Participant Code	Tentative Nature of Science			Difference between Observation and Inference			Creative and Imaginary Nature of Science		
		informed	transitional	naïve	informed	transitional	naïve	informed	transitional	naïve
1	E1		x				x			x
	K1	x			x			x		
2	E2		x				x			x
	K2			x			x		x	
3	E3			x			x			x
	E4			x			x			x
4	E5			x			x			x
	K3			x			x			x

K: Female E: Male

In Table 1, it is revealed that all of the students, except one (K1), had naïve or transitional views about the tentative nature of science. In this case, most of the students believed that scientific knowledge is true and will never change. Regarding the uncertainty factor of science, the answers given by them to the first three questions in the interview were taken into account. The first of these questions is about whether the scientific information in science books will change in the future. Five of the students stated that they would not change this question. The student coded K2 said that "*scientists searched and found the right information and wrote it in the books, so it doesn't change*", while the student coded E5 said, "e*veryone saw* *that there is correct information, so they wrote it in the book. It does not change*.' From this, it was revealed that the students believed that the scientific information was correct and that they could not be included in the science books if they were not accepted by everyone. Similarly, from the answers given by the students to the second and third questions, it was seen that they firmly believed in the information described in the science books about the structure of the atom and dinosaurs.

In addition to this, the views of the other two students are as follows:

“Scientists have seen the structure of the atom themselves” [E3]

"They combined the fossils and found out what the dinosaur looked like. They are sure of the figure they have found” [K3]

However, the views of two of them on this subject were classified in the transitional category.

‘Some information never changes, for example, the shape of the world is round, this never changes. But information about colors may vary. New colors may come out' [E2]

Only one of the students' views about the change of scientific knowledge before the teaching was classified in the informed category.

'Yes, it can change because as time progresses, new things emerge, for example, no one thought that they could see images on the phone before, but now these are done [K1]

The views of all but one about the difference between observation and inference were classified in the naive category.

[Scientists] are sure that they see the shape associated with the atom and its structure [E4]

[Scientists] saw dinosaurs by looking [K3]

These results made it clear that many students do not know the difference between inference and observation.

In this dimension, the views of the same student (K1) were classified in the informed category.

[Scientists] measure the fossils they find, try to combine them, and say something about the shape of the dinosaurs [K1]

Six of their views on the imaginative and creative nature of science were classified in the naive category. In this context, students who cannot think abstractly cognitively reported that scientists have seen the picture of dinosaurs or themselves, and even if they have not seen it themselves, they have always listened to it from someone who has.

In this dimension, one student's (K1) views were informed, and another student's (K2) were classified in the transitional category.

"Scientists use their imaginations in what they do and think it would be better if I did this" [K1]

Table 2 below includes the final profiles of students about the NOS based on the interview data.

Table 2

Final profiles of students about the nature of science

Group	Participant Code	Tentative Nature of Science			Difference between Observation and Inference			Creative and Imaginary Nature of Science		
		informed	transitional	naïve	informed	transitional	naïve	informed	transitional	naïve
1	E1	x			x			x		
	K1	x			x			x		
2	E2	x			x					x
	K2	x			x			x		
3	E3			x	x			x		
	E4	x			x			x		
4	E5	x			x			x		
	K3	x			x			x		

K: Female E: Male

At the beginning of this study, only one of the students' views on the tentative nature of science was classified as informed, but then the views of all the others, except one, were changed to informed. From the answers given by them to the questions in the last interview, it was revealed that they started to think that scientific knowledge could change for many reasons.

"If scientists reach different data, their previous thoughts may change" [E2]

"Scientists cannot know scientific information exactly, they solve the case using their imagination and creativity" [K3]

Moreover, it is significant that all of the students stated that scientists cannot know the structure of the atom exactly and cannot be sure about the appearance of dinosaurs.

"Scientists can never know exactly what dinosaurs looked like because they couldn't see it with the naked eye" [E1]

"Scientists cannot know the outward appearance of dinosaurs. While drawing, they draw by imagining" [K2]

At the beginning of this study, only one of the student's views on the difference between observation and inference were again classified as informed, while after the teaching, all of the views were assigned to this category.

"Scientists can only guess what dinosaurs looked like" [E2]

"Scientists construct the shape of dinosaurs in their heads" [E3]

"Since an atom cannot be seen with the naked eye under a microscope, scientists have guessed it by looking at the data" [E4]

At the beginning of this study, only one of the students' views on the imaginative and creative nature of scientific knowledge was again classified as informed, but after the teaching, the views of the others, except one (E2), were assigned to this category.

"Scientists imagine what dinosaurs looked like" [K1]

"A scientist without imagination cannot be a good scientist" [E3]

Discussion

It is known that students at the K-12 level, who do not receive special education for teaching the NOS, mostly have naive views on the nature of science (Akerson & Donnelly, 2010; Akerson et al., 2011; (Akerson et al., 2013; Alan, 2014; Celikdemir, 2006; Demirel, 2010; Dogan & Abd-El-Khalick, 2008; Khishfe & Abd-El-Khalick, 2002; Kucuk & Cepni, 2015). In support of this claim, the views of the 4th-grade primary school students were classified in the present study about three important elements of the NOS under the category of naive or transitional except for one student (see table 1). However, to solve the aforementioned problem, a new teaching material was designed apart from the methods employed in the literature and its value was measured. It is clear that when the material was applied almost all of the students turned their views on the three aspects of the NOS from naive to informed (see table 2). Frequent reminders by the second researcher who made the teaching to the students that they should think of themselves as scientists throughout the activity were effective in this success claimed by also Kucuk (2006). That is, on the one hand, the students collected data to examine the cause of the accident by running a questioning process throughout the activity, brought these data together, and were encouraged to make explanations in this way. The interestingness of the subject made the students continue to question with excitement from the beginning to the end of the activity. In this process, the researcher provided unique opportunities for them to establish relationships between the groups' consideration of different data, not including some data in their explanations, and ultimately inferring different meanings, and referring to real lives in the lives of scientists. Meanwhile, it has been noticed that the number and quality of the data can change the scope of the explanations and finally, due to the possibility of adding new data to the data, it was realized that the explanations made were limited by the imagination and creativity of the groups. Now, the researcher referred to scientific events and emphasized that experiences similar to children's experiences were encountered by scientists in their work. As a final point, it has been stated that the data collected after the observations are raw findings and the effort to produce meaning from them is inference. By giving scientific examples to this, it is explained what is observed and what is inference in the activity. In this context, it is clear that the activity employed in the current research is enriched with reflections on science, as it offers the opportunity to directly teach the NOS, as in the activities brought to the literature by (Lederman & Abd-El-Khalick, 1998). In the end, explicit reflective teaching like science has achieved targeted success with primary school level children, supporting the existing literature (Khishfe & Abd-El-Khalick, 2002; Kucuk & Cepni, 2015). It has been revealed that the activity produced in this study can be used functionally to fill the real gap.

Conclusion

Teaching the NOS activity designed and implemented within the scope of this study in an explicit-reflective way has led to the fact that, except for a few of the students, the views they have about the tentative inferential, imaginative and creative nature of science can go from the "naive" level to the "informed" level. From this point of view, it is believed that the explicit-reflective nature of science teaching activity is successful in teaching students the three elements related to the NOS. That's why a reflective nature of science approach should be preferred in teaching students about the NOS. In other words, students should make connections between the activities they carry out and the elements related to science and the nature of science, share these with their peers, experience ways of reaching scientific knowledge and reflect on it. It is known that students who know that science is not static but dynamic, tend to contribute more to science. From this point of view, if the NOS is taught to students correctly, it will be easier for students to comprehend that science and scientific knowledge have a dynamic structure, and students will want to make more effort to engage with it and reveal new things. Innovative opportunities should be provided for students to take a more critical view of and constantly criticize scientific information that they perceive to be not 100% correct. In this way, in-class discussions can increase the process of science lessons. This can lead to new learning. Accompanied by these explanations, the material used in the present study could be effective in teaching the NOS by revealing the aforementioned outputs for students at the primary level.

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