Story telling: research and action to improve 6th grade students' views about certain aspects of nature of science

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Abstract

This study is a four-week section of ongoing attempts that aim to improve 6th grade students' understandings of the nature of science. The study was carried out in a sixth grade science and technology class at a rural middle school with 15 students on the basis of action research methodology. During the study, four different stories based on the history of science were read and narrated in the class, along with regular class activities, for eight class hours. The teacher kept journals for every class and conducted semi-structured interviews with the students. The data collected from these sources were examined by employing descriptive analysis. It was found that both the breadth and depth of the students' conceptions of the tentative nature of science were improved after four weeks of action research-based instruction.

Keywords: action research, history of science, nature of science, story

Introduction

The Nature of Science and History of Science in Science Education

Two of the most important factors that influence and shape today's life are science and technology. Many influential organizations, as well as government institutions, have declared science literacy as the main purpose of science education for all students (AAAS, 1993; MEB, 2005; NRC, 2012; NSTA, 1971; OECD, 2006). The nature of science (NOS) is considered a fundamental part of scientific literacy (Akerson, Abd-El-Khalick & Lederman, 2000; National Research Council (NRC), 2012). Thus, one of the central goals of science education is to develop students' views of NOS (NRC, 2012). Accordingly, promoting a contemporary view of NOS has become one of the major goals of developed and developing countries all over the world (Akerson, Abd-El-Khalick & Lederman, 2000). Lederman (1992) explains NOS as understanding of beliefs and values that are embedded in science, the ways to generate scientific knowledge, and the development of scientific knowledge.

Even though there is no one shared view of NOS, the following tenets are considered to be at the core of NOS and accepted by many science educators at the K-12 level (Lederman, Bell, Schwartz & Abd-el-Khalick, 2002).

- The empirical nature of scientific knowledge;
- Observation, inference, and theoretical entities in science;
- Functions of and relationships between scientific theories and laws;
- The creative and imaginative nature of scientific knowledge;
- Scientific knowledge is partly the product of human inference;
- The theory-laden nature of scientific knowledge;

- The social and cultural embeddedness of scientific knowledge;
- The myth of the scientific method (the lack of a universal recipe-like method for doing science);
- The tentative nature of scientific knowledge.

Teaching these main tenets of NOS has become a very crucial aspect of school science. When the related literature is examined, it can be seen that there are three approaches that are mostly employed to teach NOS (Smith, 2010):

- The Implicit Approach;
- The Explicit (and Reflective) Approach;
- The Historical Approach (explicit or implicit).

Implicit Approach: The advocates of this approach claim that students are able to develop a contemporary view of NOS while learning through inquiry by pretending to be scientists. In this process, students are expected to determine a problem; try to find an appropriate way to solve the problem; collect, analyze and interpret data; come up with a conclusion; redesign explorations; and lastly, form and revise theories (NRC, 1996). They should also share their results with their peers. However, related research has reported conflicting evidence regarding the effectiveness of the implicit approach (Khishfe & Abd-El-Khalick, 2002; Lederman, 1992). Ayvacı (2007), for example, reported that students rarely carry on the inquiry process well; and thus, they may be unable to gain insightful ideas regarding NOS. Similarly, Lederman (1992) claimed that an inquiry-based implicit approach was not effective for improving students' understanding of NOS to a desired level. Khishfe and Abd-El-Khalick (2002) pointed out that students' science process skills and science conceptions would be developed by an inquiry based science class, but not their NOS views, because students are often unclear about the learning aims of teaching activities related to NOS. In this sense, NOS understandings are cognitive instructional outcomes that should be intentionally targeted in teaching.

The Explicit and Reflective Approach: The explicit teaching of NOS advocates that teaching materials are purposefully designed to address each of the tenets of NOS that are mentioned above. Akerson and Hanuscin (2007) found that the explicit approach is a useful way to change students' and elementary teachers' views about NOS and to become more informed. Related comparative research has also shown that the implicit way of teaching NOS is less effective than an explicit approach (Akerson, Abd-El-Khalick, & Lederman, 2000). Khishfe and Abd-El-Khalick, (2002) reported that explicit and reflective approach is more effective than implicit approach to improve students' views of NOS. They also pointed out that the reflective aspect of NOS teaching is crucial, since it provides opportunities for students to analyze the activities in which they are engaged from various perspectives (e.g., a NOS framework); maps connections between classroom activities and those undertaken by others (e.g., scientists); and draws generalizations about a domain of knowledge (e.g., epistemology of science).

Historical Approach: Another way of teaching the NOS that can be either implicit or explicit involves the History of Science (HOS). This approach, which will be further examined in this essay, focuses on the process of an activity that helps develop recognition of the process of scientific knowledge generation and scientific knowledge within the social and cultural context (Doğan & Özcan, 2010).

Background of the Study: Importance of HOS in Teaching NOS

According to socio-cultural theory, students would develop a better understanding about the culture of science, as well as how science and scientists work, if teachers utilize HOS while teaching science concepts that have also been found useful for teaching NOS (Abd-El Khalick, 2002; Güney & Şeker, 2012; Irwin, 2000). Solomon et al. (1992) also emphasized the importance of HOS while teaching NOS. The main argument for utilizing HOS is to help students learn how to interpret and appreciate scientific claims (theories, principles, models, or hypotheses) within their time and social structure (Kahraman, 2012). Students' understanding of NOS was found to increase remarkably by utilizing HOS as well (Clough, 2009; Irwing, 2000; Kruse, 2010; McComas, 2008).

Students come to class with some prior conceptions and perceptions about everyday phenomena (Karataş, Ünal, Durland & Bodner 2013; Nakhleh, 1992; Orgill & Sutherland, 2008; Osborne, 1982; Palmer, 2001). Research has shown that historical development of scientific knowledge and students' ideas have many commonalities (Monk & Osborne, 1997). In this respect, HOS provides students a chance to compare their ideas about natural phenomena with the historical development of ideas about those phenomena. Students can see that their ideas were accepted in history but changed according to concrete evidence. They might see flaws in their ideas and learn how to improve them by reflecting on HOS. This process can provide a valuable opportunity to illustrate the tentativeness of scientific knowledge to students. It can also be useful for teachers to learn more about students' thinking

(Rudge & Howe, 2009). Teachers might grasp ideas about students' possible misunderstandings from HOS and consider these while planning their courses.

In addition, HOS might be utilized to depict the relationship between science and many issues in society, including personal, ethical, cultural and political concerns. For example, students can interpret scientific knowledge in the historical and social context with the help of HOS. This enables students to comprehend that scientific knowledge and theories that were seen as valid and reasonable in their period might be seen unduly as wrong or simple today. Furthermore, HOS might be useful to examine the humanist aspect of science with students (Klassen, 2007), because they may be curious about scientists' social and cultural backgrounds and the influence of these factors on scientists' thoughts and research. This might help students engage in science as part of their daily lives. Additionally, HOS may allow students to empathize with scientists and with the social environment associated with the scientific community (Doğan & Özcan, 2010); and HOS can be utilized to learn more about science, scientists, scientific knowledge, the scientific process and progress. Students may notice the evolution in our understanding of a phenomenon over a period of time, enabling them to understand more about the scientific process (Kim & Irving, 2010). Thus, learning HOS might help students to learn the story of scientific endeavor (Klassen, 2007).

HOS Based Stories in Teaching NOS

Several studies have reported that HOS is a useful and successful way to teach NOS (Irwin, 2000; Kim & Irving, 2010; Lin & Chen, 2002). One way of using HOS for teaching science is via stories, which are very effective tools for increasing students' interest and motivation for science (Klassen, 2007). Stories play an important role in the culture of many civilizations, so teaching science lessons through stories can be an attractive learning tool for students. Stories are not just for fun or motivation. Klassen (2007), for example, asserted that stories are beneficial to developing problem solving, critical thinking, and inquiry skills. Students can think of themselves as the main character of a story and try to solve a problem. Students can also criticize the ideas of different characters in a story, helping them learn while having fun.

Stories that are based on HOS might also change students' and teachers' traditional roles in class. The characters of stories become a guide that enables the meaning-making process to become easier for students (Silva, Colleiva & Malachias, 2009). Thus, students may comprehend that science is made of multiple complicated concepts, theories, and laws. On the other hand, students may have a difficult time understanding science concepts within a given paradigm when they are not aware of the differences between the related predecessor and successor theories (Gericke &Hagberg, 2007). Through stories, students may be able to see the challenges and problems in scientific methods that they employed to better understand the phenomenon, as well as the inferences from the data and results in the course of history. In other words, through HOS, students may be able to better conceptualize the inquiry process (Singleton, 1997). Likewise, Hill and Baumgartner (2009) claimed that HOS-based stories are useful for organizing concepts in cognitive schema. In this respect, Renninger (2009) asserted that students were interested in HOS-based stories, and this motivated them to learn about science. Other researchers, including Kruse (2010) and Smith (2010), have also emphasized that HOS-based stories have positive effects on teaching NOS, as well as scientific content. Most of the reviewed studies about teaching NOS via HOS investigated the progress towards a more articulate view of NOS. In the light of the cited literature, HOS-based stories for the teaching of NOS were chosen as the main approach for carrying out this study.

The purpose of this study was to diagnose and improve 6th grade students' views of NOS. This study focuses specifically on a few aspects of NOS, including the tentative nature of scientific knowledge; subjectivity in science; and certain characteristics of scientists and their work environment.

Keeping this purpose in mind, the research questions that guided this study are as follows:

- *How do stories about the history of science affect 6th grade students' views regarding the tentative nature of scientific knowledge?*
- *How are students' views about the characteristics of scientists changed through the use of stories?*
- *How are students' views about the work place in which scientists conduct scientific research changed?*
- *How are students' views about the subjective nature of science changed through the use of stories?*

Methodology

This study was carried out on the basis of an action research methodology, because one of the researchers, who will be referred as "the teacher" from now on, is a practitioner science teacher who teaches science and technology courses at a rural middle school in the north-western region of Turkey. There were 15 students in the 6th grade class. The teacher noticed that her 6th grade students did not pay attention to science classes and conveyed an absolute view of scientific knowledge; she mentioned the problems that she has in her class to a professor (the second author). To address these issues, we selected collaborative action research as the methodology for this study. Capobianco (2007) expresses that the aim of action research is "to improve the quality of teaching and learning as well as the conditions under which teachers and students work in schools". In the action research process, teachers going about their usual work of teaching, but a scientific process that includes a cycle of planning, action, and reflection is utilized. Collaborative action research involves the teacher and university researcher joining together to examine and take action to deal with different issues and concerns about the practice (Capobianco & Feldman, 2006). Firstly, we identified the problem more clearly by describing the classroom and exchanging ideas. We agreed on a design of teaching with HOS based stories and planned the research process. Every week, we met and reviewed our plan and the treatment process.

As all methodological frameworks, action research has some limitations; these are evident in this study as well. One of the main limitations of action research concerns bias of the researcher as teacher. However, many precautions were undertaken to maximize the rigor of this study, as described in following sections. Among these, a second researcher overviewed all steps of the study; every step was noted and reflected by the teacher; multiple data sources were utilized; and an overlap was sought between the raters in data analysis (Melrose, 2001).

HOS story cases and teaching science

Four HOS stories, including "To Dreams," "Restless Creatures," "Where," and "Like Gold" were derived from a book titled "Scientific Goofs: Adventures Along the Crooked Trail to Truth," written by Billy Aronson (2010) and implemented in the science classes. These HOS-based stories convey a few of the tenets of NOS described by McComas (2005). Table I shows the stories and the aspects of NOS that they address, which we believe that students may acquire while reading and discussing the stories in class.

Table I. The stories and the elements of NOS that they address

The story	Content of the story	Elements of NOS infused (Based on McComas, 2005)
"To Dreams"	The story is about dreaming about flying and the related scientific developments.	Science demands and relies on empirical evidence. There is no one-step scientific method by which all science is done. Experiments are not the only route for knowledge. Scientific knowledge is tentative but durable.
"Restless Creatures"	The story illustrated how scientists examined a common belief that ants or worms are generated without a reason and spontaneously in a scientific way.	Scientists may hold different ideas about the same phenomenon. Science demands and relies on empirical evidence. Knowledge production in science shares common methods and shared habits of mind, norms, logical thinking, and methods. Scientific knowledge is tentative but durable.
"Where"	This story is about the geographical discoveries era. The story tries to answer how some of the notable explorers discovered the world.	Science demands and relies on empirical evidence. Scientists can have different ideas about the same topic. Scientific knowledge is tentative but durable.
"Like Gold"	This story tells us how chemistry as a field of science emerged from alchemy.	Science demands and relies on empirical evidence. Scientific knowledge is tentative but durable.

Teaching Process

The first phase of our ongoing attempts to deal with lack of attention to science class and a comprehensive view of NOS took eight hours. At the beginning of the first class, a short discussion was established to elicit the students' prior knowledge about science and NOS. The following questions were used to start the class discussions:

- What does it mean to do science? Why are people interested in science?
- What would be the characteristics of a scientist?
- Where do scientists carry out their scientific work?

After the discussions of these questions, the teacher took notes about the students' responses. Then, she handed out booklets of stories to her class. She asked everybody to start reading the story "To Dreams" by themselves. When everybody finished reading, the teacher asked the students to summarize and tell what they understood from the story. After a few responses, the students were allowed to talked about the story and interpret each others' ideas about it. The teacher emphasized the related tenets of NOS that were represented in the story whenever an opportunity emerged. If there was no opportunity for the teacher to talk about NOS during the discussions, she specifically addressed the elements of NOS that were apparent in the stories after the discussions. In addition, the teacher asked further elaborative questions about the stories in relation to certain aspects of NOS. At the end of the class, she asked the same questions that she had asked at the beginning and took notes regarding the changes in students' comprehensions about the elements of NOS. Just before finishing the first class, the teacher decided to read the story with the whole class together to repeat the ideas, because she realized that a few students in the class do not ask questions when they do not understand.

During another three weeks, the stories were read by the teacher and the students. In every class, the teacher specifically addressed important points in the stories related to NOS. She designed her teaching with the intention that the students would be able to draw deductions about certain aspects of NOS while reading the stories. The students were required to summarize each story and what they had learned from it after the reading was finished. Moreover, the teacher deliberately addressed the certain aspects of NOS, especially the 'tentative nature of scientific knowledge' while discussing the stories. All four stories address the development and change of scientific knowledge about certain phenomenon throughout the course of history. It took four weeks to finish reading and discussing all of the stories.

Data Collection

The participant researcher, the teacher, recorded digital research journals after every class in order to describe students' behaviors and improvements. The aim of the journals was to follow up on the effects of the changes we made during the study in line with the "reflection-in-action" idea proposed by Schön (1987). The research journals included the teacher's observations; anecdotes; her reflections in and on practice and within and between class conversations with students; and students' interpretations and thoughts about stories, science, scientific knowledge, scientists, and so on.

In addition, a semi-structured interview protocol with four questions was developed by the researchers in order to grasp the students' views of NOS in a more structured way. The interview protocol was examined by an expert in science education research, and the necessary changes were made based on the suggestions. After that, semi-structured individual interviews were conducted with all members of the class. All interviews were audio-recorded in order to grasp every aspect of the students' views.

Data Analysis

The data were gathered from two different sources; the researcher journals and the student interviews. The data from both sources were subjected to content analysis. In addition, overall class engagement for the teaching process was evaluated based on a four-point scale rubric. These hierarchical four levels were determined to describe the overall status of students' engagement in the class; 1 as being low and 4 as being a high level of engagement. During the teaching process, the students were expected to demonstrate behaviors that are described below:

- Showing enthusiasm to examine the stories and ask questions curiously about them;
- Interpreting, joking and asking follow-up questions about different characters, events, situations or pictures in the stories;
- Showing willingness to respond to the questions that the teacher asks the whole class about the scientific concepts, NOS, and the stories in general;
- Coming up with a conclusion by interpreting events and situations in the stories;

- Answering the questions about events and situations that take place in the stories.

As seen in Table II, the overall participation level was defined based on the frequency of the displayed behaviors and the number of students showing these behaviors. 1: low level (0 – 3 students), 2: moderate level (3 – 6 students), 3: good level (6 – 9 students), 4: high level (more than 9 students).

Table II. Student numbers to determine course participation level

Class participation level (CPL)	Number of students showing expected behaviors
1 (Low level)	0 – 3 students
2 (Moderate level)	3 – 6 students
3 (Good level)	6 – 9 students
4 (High level)	More than 9 students

In order to improve the trustworthiness of the data and the analysis process, a professor and a doctoral candidate who are experts in keeping and analyzing reflective journals oversaw this process. In addition, another science teacher read all of the teacher's journals, and they collaboratively decided on the overall levels for each class. They had total agreement about the level of participation in all classes.

The data from the semi-structured interviews with 14 students were transcribed, and then subjected to content analysis. The students' responses to each question were coded separately, and themes were identified based on these initial codes. The transcripts were coded again two months after the first coding (Yıldırım & Şimşek, 2006). The overlap between two separate codings was relatively high for the interviews for each story: 0.83 for "To Dreams", 0.80 for "Restless Creatures", 0.85 for "Where" and 0.88 for "Like Gold."

Results and Discussion

Two different data sources were utilized in order to answer the research questions. Analysis of the data from these sources is presented together in a supportive way to show the students' views in relation to NOS. The students' views were sorted into four main categories, including the purpose of science and characteristics of scientists; places to conduct scientific research; different interpretations of the same phenomenon; and tentative nature of scientific knowledge.

Students' Ideas about the Purpose of Science and Scientists

Before starting and at the end of the first story, brief class discussions took place. The teacher's notes stated three main topics: reasons for interest in science; characteristics of scientists; and places scientists work. These notes, along with the students' ideas from the interviews, are illustrated in Table III.

Table III. Changes in students' ideas about the purpose of science and characteristics of scientists

Theme	Before Practice	After Practice
Reasons for interest in science?	To live comfortably To make our lives easier by invention	To live comfortably To make our life easier by invention To make their dreams come true To realize their dreams
Characteristics of scientists	Doing research Reading a lot of books Being curious Being very successful Working in a laboratory	Doing research Reading a lot of books Being curious / Asking questions Being successful Working tirelessly in laboratory to do experiments Learning from others' and their own mistakes Being intelligent Being organized, hard working, and confident
Places scientists work	Laboratory or library	Laboratory or library Workshop / Factory Outside (a place where they can practice)

As seen in Table III, the students' views about reasons for interest in science were enhanced during the study. The students said that scientists are interested in science because they want to invent new things. The researcher asked "Do scientists always work to invent something? Don't they ever think about how it snows or rains? Why don't they think of these kinds of things?" and the answer was "You are right, but they had already found the answers to these kinds of questions, and now they are trying to invent something new." The responses to these questions show us that the students generally think that scientists must work to be useful for society or humanity, but that they do not pay much attention to their own curiosity. Erenoğlu (2010) stated that most popular idea regarding the aim of science for 5th grade students was to make inventions and to do experiments. Kara (2010) also reported that students, even at the university level, may still have the idea that science is for improving life quality rather than fulfilling the need for knowing. As a result, students generally do not perceive science as an enterprise to understand the universe (Karataş & Bodner, 2006; Karataş, Bodner & Çalık, 2009). Therefore, teachers should emphasize and show students that there are many issues that science deals with in science classes. After the first phase of the ongoing teaching process, a few students changed their ideas and expressed that "science is a field of study that tries to understand the world, the close and distant environment and the universe in general."

As can be seen in Table III, the students developed new ideas about the characteristics of scientists during practice. Only Student 04 answered "I don't know" about the characteristics of scientists in the interviews. The most repetitive characteristic of scientists noted in the students' responses was "being curious," along with "doing research."

At the end of the teaching module, we asked students whether they would consider being a scientist in the future or not. Three out of fourteen students asserted that they would be scientists. As a follow-up question, we asked them "why?" Student 02, who does not want to be a scientist, said, "If I study hard, I can be a scientist, but I don't want to be a scientist." Many others reported that they could not become scientists, as they do not have scientists' characteristics. Four students, for example, pointed out that as they are not pertinacious, they cannot be scientists. Two students indicated that they were not clever enough to be scientists. Student 01 pointed out that he is not curious enough to be a scientist. Student 06 said that she is not a hard worker and does not like studying. We found that the students' ideas changed according to the stories and class discussion. While reading and/or narrating the stories, the teacher noticed that the students were really impressed that scientists conducted so many experiments and could study for years to achieve their aims. The following excerpt is a good illustration of the changes in Student 08's view regarding the characteristics of scientists, as well as the scientific research process. He expressed his ideas in the class discussion after reading the story "To Dreams." "I thought that scientists conduct experiments two or three times and they achieve their goals. But now, I can see that they need to study many long hours to achieve results." Another interpretation was expressed by Student 13: "Scientists are so hardworking; they try again and again to achieve their aims."

Students' Ideas about Places to Conduct Scientific Research

When the students were asked where scientists do their jobs, their ideas were limited to "laboratories" at the beginning of the first class, except one student who indicated that scientists can also work in libraries (see Table III). Zimmerman and Bell (2012) claimed that students perceived observing and experimenting in school science as only the scientific activity in their lives. Similar to Çakıcı and Bayır (2012), our students think that a laboratory is a suitable work place, because it is quiet and has all the needed equipment and tools. Likewise, our students may have had some pre-conceptions about science, scientists and their work place before taking this class based on conventional wisdom and the mainstream view that "scientific knowledge is generated in controlled laboratories" (McComas, 1997). These widely-shared impressions might affect our students' ideas about science and scientists. Other sources of this laboratory image might come from pictures and figures about scientists in science textbooks or media that always show scientists working in laboratories (Karatas, Micklos & Bodner, 2011). However, the HOS-based stories helped students change and enrich their views, as seen in Table III, because real examples from the HOS showed the students that scientists can study in any place that is suitable for their research.

The students also mentioned two other places where scientists can study/research, as seen in Table III. When asked where scientists carry on their work during the interviews, all of the students expressed that they can work both outside and in a laboratory. Four students talked about Newton and gravity as an example of outside work. Student 10 expressed that "Scientists can work inside or outside; for example, to do experiments, they work in laboratory. They could observe stars and planets outside." Four students gave the exact examples from the stories that were read in class. Three of them gave the same example about flight from the story "To Dreams." Student 06, for instance, expressed that "…to have flight, scientists worked outside, like in the first story." Student 03 cited the story "Like Gold" to support his view that experiments can be done either inside or outside. Nine out of fourteen examples that the students gave were addressed in the class/stories. Based on these findings, we can say that teaching with HOS-based stories altered the students' views of places where scientific research takes place.

Students' Ideas about Subjectivity in Science

In her journals, the teacher noted that only one week (two hours) of the practice included discussion of the question"Have scientists got any different ideas about the same topic?" while reading the story "Where?" All of the students claimed that scientists can have different ideas on the same topic, but they could neither explain their ideas in detail nor back up them. Then, the teacher realized that the students did not understand the topic from their confused looks and puzzled faces. In addition to the story, she provided different examples from daily life. She asked, for example, if the blackboard is big or small. Some students responded that it was big; some of them claimed that it was small. After the teacher got all of their responses, she emphasized personal opinion and explained that the students' decisions are based on their previously seen and experienced blackboards. Then, she gave some examples to support the idea in the story. The teacher provided another example of this nature to elaborate that background knowledge and experiences might affect interpretations. However, a few students still could not answer the question: "Have scientists got any different ideas about the same topic? Why?" They were also surprised and doubtful. Even though all of the students mentioned that "different people think in different ways," none of them comprehended why different scientists have different ideas on the same topic, so they could not explain it. This might be caused by the idea that observations in science are purely objective, which is one of the myths about science. After the intervention, most of the students could interpret why scientists have different ideas about the same topic. In addition to the teacher's field notes, the interviews supported this finding. All of the interviewed students said that scientists can have different ideas. Student 07 expressed that they behave according to their prior knowledge. Another pointed out that scientists' feelings shape their ideas; especially what they like or dislike. Student 05 focused on living in different places by addressing the story told in the class "Scientists can think differently… Maybe… they are from different places and they don't know each other, like in the story." The rest of the students' responses addressed differences among scientists, but they could not provide reasons for these differences, even though they were intentionally solicited.

They think differently because they are different people. (Student 10)
Different people can have different ideas. (Student 06)
Of course they can have different ideas; they don't have to think the same way. (Student 08)

Students' Ideas about the Tentative Nature of Scientific Knowledge

One of the important aspects of NOS is the tentative nature of scientific knowledge. Several studies reported that students at all levels of education think that scientific knowledge is absolute (Çelikdemir, 2006; Khisfe & Lederman, 2007; Kılıç, Sungur, Çakıroğlu & Tekkaya, 2005). In other words, many students believe that scientific knowledge cannot change. Others believe that scientific knowledge is not tentative, but rather that new knowledge can be added to the old; in other words, scientific knowledge is cumulative (Çelikdemir, 2006). This view illustrates that students could not examine and comprehend how science progresses. To address this issue, HOS provides a chance for students to explore the development process of scientific knowledge at its cultural and social roots with a historical lens. In this study, after reading each story, it was emphasized that scientific knowledge can change by addressing the findings in the stories and comparing the findings at the beginning and end of the stories. The teacher noted in her journal that the students realized from different examples in the stories that scientific knowledge can be organized or changed according to new evidence and findings.

All students but two asserted that scientific knowledge can change over time when asked in the interviews after the teaching. Three students grounded their ideas in an example of the change in atom models from John Dalton to Marie Curie. Two students did not provide any examples even though they were asked promptly. Another student expressed that new information can be added to old, but he could not give an example. Another student confused science with technology by giving TV as a constantly improving invention: "CRT televisions are old. Technology has improved, and they become better." A total of five students provided examples for the tentative NOS from the stories that they read; two from the story "To Dreams"; two from the story "Like Gold"; and another one from the story "Restless Creatures." An illustrative excerpt from an interview is provided below:

> *Teacher: Scientists attain scientific knowledge by researching, observing, doing experiments. Do you think about whether all this knowledge will change in the future?*

Student 08: Yes, they will find new things.
Teacher: Can you explain your thoughts with an example?
Student 08: For example, in the "Particular Structure of Matter Unit" in our science courses, we learned that people believed that atoms are indivisible in history. That was Daltons' idea. But we know now that it's wrong.
Teacher: Why wrong? Please express your thoughts.
Student 08: Curie and Becquerel studied on this topic and found that atoms are fissionable.

All but two of the students mentioned that scientific knowledge can change over time. Eight of these, more than half of the class, expressed and supported their views with correct examples or explanations. Thus, HOS-based stories can be considered as an effective tool for teaching about the tentative nature of scientific knowledge, but it cannot be claimed that this is enough; it seems that the students gained the right ideas, but some of them could not elaborate these ideas in greater detail (e.g., providing examples). Two students thought that scientific knowledge does not ever change. Student 09 gave as an example that "water boils 100^0 C all the time." Other two students talked about technological inventions and innovations. These cases show that some students' views are still not very well developed. Students generally think that results based on empirical evidence never change, such as laws; because they are tested so many times, they will always give the same results. Çakmakçı, (2012) reported similar results with pre-service science teachers. The stories were very useful, but further elaboration via examples is needed to support these students.

Description of General Class Participation

The overall level of class participation (CPL) (or engagement) for each story is defined here according to the scale described in Table II, As seen in Table IV, the story titled "Restless Creatures" had the lowest engagement and participation. The story "To Dreams" had the highest class participation.

Table IV.The students' class participation and behaviors during the study.

Stories	CPL	Student behaviors
"Restless Creatures"	2	Showing enthusiasm to examine the stories and asking questions curiously about them Showing willing to respond to the questions that the teacher asks the whole class about the scientific concepts, NOS, and the stories in general Coming up with a conclusion by interpreting events and situations in the stories
"Where" and "Like Gold"	3	Statu 2 + Answering the questions about events and situations that take place in the stories
"To Dreams"	4	Statu 3 + Interpreting, joking and asking follow up questions about different events, situations or pictures in the stories

When asked directly, all of the students said that "they like the stories," but the teacher's observations contradicted the students' responses. The length of the stories might cause differences in class engagement. Based on observational data, including the students' answers to the teacher's questions; their degree of attention to the story; the quality and quantity of the questions asked about it; and other behaviorssuch as interpreting or joking about the story, it seems that not all of the students were really interested in the stories. As the teacher noted in her journals, about half of the class showed enthusiasm for the class activities, especially the stories. As a different approach, HOS-based stories drew most of the students' attention to the class activities, which has been similarly emphasized in the related literature (Klassen, 2009). However, the stories might be too long for some students, and some of the story topics might not be as interesting as others.

The whole class was willing to read the stories out loud except one student who had problems with his voice. The students put themselves into the story as one of the characters and tried to solve the problems. This helped them solve problems and make sense of NOS (Klassen, 2009). While the stories were being read, the students asked some questions, such as "could they produce gold?"; "what does Keratokis mean?"; "is there anybody who believes in spontaneous generation of living things?" Moreover, the students asked to repeat some parts of the stories that they did not understand, such as the Arabic scientist Alfragan's errors in calculation of the size of the world. In addition to asking questions, the students made jokes and commented about the stories. For instance, in the story "Restless Creatures," the students laughed out loud at the claim that frogs come from clouds when it rains. Then, they commented on the story by saying "this story is so funny," after they read some of the early beliefs about the creation of the animals, such as "sweaty shirts give birth to a mouse with wheat, and dead flies create new flies with fish in the pond." Students generally liked the HOS-based stories and enjoyed the time they spent reading them. This enabled more active engagement in the class discussions and other information provided by the teachers. The students were observed to have "serious" fun, as with Liu and Falk's (2014) assertion, rather than being "reluctantly" involved in activities.

Furthermore, it was observed that the students were surprised from time to time while reading the stories. In the story of "To Dreams," the students had reactions such as "Oooh!" or "Hummm!" Student 09, for example, shouted out, "How can they (birds) be eight times stronger than a person?" while she came across the sentence "If birds were the same size as humans, they would be much stronger." In another example, Student 02 asked, "Teacher! Did they (scientists) really believe in spontaneous generation?" The students realized that scientists can also make mistakes; this shows that science is a human endeavor (Klassen, 2009; Silva,Colleiva & Malachias, 2009) and motivates them for learning science. The teacher's journals also identified similar behaviors in the class at different times.

The students also had chances to interpret the stories and come up with some conclusions about NOS. Analysis of the teacher's journals revealed that the students could draw deductions about NOS while reading the stories. For instance, Student 4 stated, "As scientists try something, they learn new things. They also learn new things from their own mistakes, and they benefit from them for new research" after the story "Like Gold." The students pointed out that Christopher Columbus had to support his claims with some evidence, as mentioned in the story "Where". The NRC (2012) report points out the importance of students' making comparisons, interpretations, and deductions from observations and experiences. Evidence from the journals helps us infer that this research encouraged students to improve in that respect, as well. The HOS-based stories were very motivational for the students, and they were more active and took more responsibilities when compared to earlier classes. Thus, as Kruse (2010) and Smith (2010) emphasized, the HOS-based stories had a positive effect on the teaching of NOS.

In the researchers' journals, the halting ways of research and the necessary and appropriate changes during the process were dealt with by considering the arguments and ideas from the observations of the teacher. For example, the teacher initiated an argument after the students read the story completely in the first practice period. In this period, it was observed that the students did not ask about words when they did not know their meanings. Furthermore, it was observed that the students could not understand some elements of NOS while the stories were being read. Thus, the teacher emphasized that the story should be read in a high tone of voice. This method turned out to be very useful and effective.

In the last lesson, the teacher asked "What have you learnt from the stories? Are there any changes in your ideas?" Almost all of the students raised their hands, and many expressed their changing views regarding the process of scientific work and what scientists do. Here are three students' responses as illustration:

> *Scientists do not work only in a laboratory, they can work in a library or outside. (Student 05)*
> *They believed in 'spontaneous generation', but nobody believes that now. (Student 02)*
> *I learned how scientists work. (Student 14)*

As can be seen in Table III and from the students' expressions above, the students' views about NOS were improved. The students had learnt more about NOS at the end of four weeks, as they stated. This process provided the students more opportunities to understand science, scientists, scientific research, the scientific process, and progress of scientific knowledge. Similar findings are reported by the related literature that emphasizes HOS as a useful tool and context for learning NOS (Doğan & Özcan, 2010; Irwin, 2000; Kim & Irving, 2010; Lin & Chen, 2002).

Conclusions and Implications

The purpose of this study was to diagnose and improve 6th grade students' views of the NOS; particularly the tentativeness of nature of scientific knowledge. Based on the findings, we have reached following conclusions:

- The general class participation findings demonstrate that HOS-based stories attracted the students' attention and motivated them to engage in class activities. Thus, HOS-based stories could be useful to engage students in class and may improve their learning of science. Moreover, the students were more interested in science. In other words, HOS-based stories attract students' interest and motivate them to learn science. As Hidi and Renninger (2006) point out, greater interest in science might have prolonged effects on learning and possibly increased science aspirations in the future.

- The HOS-based stories allowed students to examine the developmental process of scientific knowledge. Thus, students' views about the tentative nature of scientific knowledge may be improved.
- A few students had had stereotypical images about science, scientists, and the work places of scientists at the beginning of the study. The teaching activities supported by HOS-based stories conveyed more realistic images of science and scientists. However, almost all of the scientists who had noteworthy effects in HOS were gifted and/or genius, so regular students might see themselves as incompetent for pursing science as career. This might also cause students to feel a lack of self-efficacy for science. Thus, while using HOS in science teaching, this important aspect must be taken into account; and the focus should be on "normal science" and scientists, as well as extraordinary/revolutionary figures.
- As subjectivity in science was only mentioned in one story and was not dealt with comprehensively, the students' learning is insufficient in this aspect of NOS.

Overall, it seems that HOS-based stories are useful tools for teaching science and NOS. They help students understand the culture of science. Based on the finding of this study, it can be suggested that HOS or HOS-based stories could be integrated into science teaching in order to enhance the interest, engagement, and understanding of science among youth.

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