An Activity on Teaching the Nature of Science: Magnetic Field Lines

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Abstract
The aim of this study is to introduce an activity on magnetic fields prepared in order to improve high school students' views on the nature of science. The activity was prepared according to explicit-reflective approach, which is one of the nature of science teaching methods. The nature of science elements intended to obtain with the activity are as follows: Changeability of scientific knowledge, its empirical nature, its subjective nature, its partly being a product of creativity and imagination, the difference between observation and inference. The activity on magnetic field lines was prepared including these elements and was expert reviewed. After revisions were made according to the views of experts, a pilot activity was implemented with five 12th grade students. The video recordings, observation notes, activity papers used in the process and opinions of the students in the activity were analyzed. At the end of the study, it was found that the students were not able to make the distinction between observation and inference; however, the desired level was reached with respect to other elements using explicit-reflective approach.
Keywords: nature of science, physics education, nature of science activity, magnetic field.

INTRODUCTION

Today, the science programs aim to produce individuals who can solve problems which they face in their own environment, who can produce various solutions to these problems, who can use scientific methods like scientists and who have science literacy (AAAS, 1990 and 1993; NRC, 1996 and 1998). The nature of science is an important component of science literacy (Driver, Leach, Millar & Scott, 1996). It is necessary to teach the nature of science in order to produce individuals with science literacy. The elements of science literacy were determined by studies (Bell, 2009; Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; McComas, 1998). These components are as follows: The scientific knowledge is open to change, the scientific knowledge has an experiment-based nature, the scientific knowledge is based on inferences as well as observations, the scientific knowledge is loaded with theories, the scientific knowledge contains imagination and creativity, the scientific knowledge is affected by social and cultural values.

The determination of views on the nature of science is important in terms of teaching the nature of science. For this reason, studies have been made in order to determine the views of students (Doğan, 2010; Griffiths & Barman, 1995; Lederman & O'Malley, 1990; Öner Armağan, 2015; Ryder, Leach & Driver, 1999; Sadler, Chambers & Zeidler, 2004), the views of pre-service teachers (Abd-El-Khalick, 2001; Abd-El-Khalick, Bell & Lederman, 1998; Bell, Lederman & Abd-El-Khalick, 2000; Palmquist & Finley, 1997), the views of teachers (Abd-El-Khalick & BouJaoude, 1997; Lederman, 1999; Schwartz & Lederman, 2000) on the nature of science. As a result of these studies, it has been found that the participants had incorrect or insufficient knowledge of the creative nature of the scientific knowledge, the structures of theories and laws, the structures of scientific methods and the characteristics of scientists. In his study, Lederman (1992) has found that the most important variables that affect students' views on the nature of science were the special educational behaviors, activities and behaviors during the lecture. Based on this, a need for preparing the nature of science teaching activities in order to teach the elements related to the nature of science has emerged. The hypothesis boxes and black boxes used in the studies of Abd-El-Khalick and Lederman (1998) can be given as an example of these teaching activities.

Thus, after the studies which found the incorrect and insufficient knowledge of the nature of science, conducting studies in order to improve this knowledge has become a necessity. For this purpose, three different approaches have been used in order to teach the nature of science effectively; the explicit-reflective, implicit and historical approaches (Akerson, Abd-El-Khalick & Lederman, 2000). *Historical Approach:* In this approach, the students participate in activities in which they can discover the development of scientific theories in the context of their social and cultural properties of their respective historical era. It has been seen that conflicting results were obtained in studies on the effects of the historical approach on students' knowledge of the nature of science (Solomon, Duveen & Scot, 1992). *Implicit Approach:* Proponents of this approach claim that students' understanding of the nature of science will improve by itself when they participate in scientific activities such as inquiry-based learning or scientific process focused teaching (McComas, 1993; Moss, Abrams & Robb, 2001**).** *Explicit-Reflective Approach:* Proponents of this approach claim that the understanding of the nature of science is a cognitive learning gain, that it cannot be expected to improve by itself and thus, that it should be taught clearly and by thinking about it deeply (Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000). Studies have been conducted in order to find the effects of activities prepared according to these approaches on the views of participants on the nature of science (Abd-El-Khalick, 2002; Ayvacı, 2007; Beşli, 2008; Küçük, 2006; Lederman & Abd-El-Khalick, 1998; Lee, 2007). It is still an ongoing debate which of these approaches is the most successful under what circumstances. (Abd-El-Khalick et al., 1998; Abd-El-Khalick & Lederman, 2000; Driver et al., 1996; Khishfe & Abd-El-Khalick, 2002). At the same time, it is another matter of debate whether the activities should be designed based on the subject area or independent from the subject area (Abd-El-Khalick et al., 1998; Bell et al., 2000; Brickhouse, Dagher, Letts & Shipman, 2000; Clough & Olson, 2001; Lederman et al., 2002; Ryder et al., 1999). Examining these debates, we decided to design an activity using the direct-reflexive approach and based on a subject field.

PURPOSE

This study has two purposes: the first one is to design a nature of science activity based on magnetic field lines and compatible with explicit-reflective approach to improve the opinions of high school students on the nature of science. The second one is to introduce this activity by stating positive and negative points encountered during development and implantation process, so that science teachers can use this activity in their own classes. The research questions addressed in this paper are as follows:

(i) Is it possible to develop nature of science activities depending on the subject of magnetic field?
(ii) Is it possible to apply these activities to the high school students?

METHODS

The explicit-reflective approach was preferred while preparing the activity with the influence of studies in the literature which stated that this approach was more effective in terms of teaching students the elements of the nature of science (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Brickhouse et al., 2000; Clough & Olson, 2001; Ryder et al., 1999). Also, it is suggested that explicit-reflective, historical and implicit approaches were limited in terms of teaching the nature of science and in order to overcome these limits, the nature of science should be taught based on a subject area (Brickhouse et al., 2000; Ryder et al., 1999). For this reason, activity was designed based on a subject field. The magnetism was selected as the subject to be used in the activity. The fact that the magnetism is a subject which students have difficulties with (Aycan & Yumuşak, 2002) and that it contains materials in line with our aim was effective in the selection.

In the design process of the activity, the activities in the literature, which were prepared independently from a science subject area were examined. (Abd-El-Khalick, 2001; Abd-El-Khalick, 2002; Ayvacı, 2007; Beşli, 2008; Cobern & Loving, 1998; Khisfe & Abd-El-Khalick 2002; Küçük, 2006; Lederman & Abd-El-Khalick, 1998; Lee 2007). Also, books about the history of science, the development of science and which ways scientists followed in their works on magnetism were examined (Kuhn, 2008; Popper, 1998; Sencer, 1998; Snow, 2001; Yıldırım, 1999; Yıldırım 2008).

After the activity was designed, the opinions of experts were taken in terms of the nature of science and physics. The activity was reviewed by a physicist in terms of compliance to the laws of physics. The activity was reviewed by three academics in terms of the nature of science elements intended to obtain with the activity. In this review, the experts rated the elements related to the nature of science in the activity, according to a Likert-type scale as "not emphasized", "weakly emphasized", "emphasized well", "emphasized very well". According to the results of the Liker-type scale, the necessary changes in order to emphasize the elements were made. The elements which were rated as "not emphasized", "weakly emphasized were reviewed and improved. Thus, after a final review, the activity was ready to be implemented.

The magnetic field lines activity consists of six steps. In the activity, the elements of changeability of scientific knowledge, its subjective nature, its partly being a product of creativity and imagination, the difference between observation and inference were emphasized. Also, the properties of scientific models, which are not part of the nature of science, will be discussed.

Since the activity is going to be implemented after the first unit of the 12th grade physics class "Magnetic Field, Field Lines, Field Strength" is completed, the students are supposed to know what magnetic field lines are and their properties theoretically. The pilot implementation was carried out in the physics laboratory with five volunteers from 12th grade students of The Çorum Boğazkale High School. The activity was completed in 45 minutes, which is the standard lecture duration. For the activity; a magnet, iron powder and a piece of glass without sharp edges (for security purposes) were needed.

The conversations and actions during the implementation of the activity were recorded in order to be reviewed later, with the permission of the students. Also, the conversations between the students, the drawings requested from the students and the reflective papers the students were asked to write were analyzed using the descriptive analysis method. In the descriptive analysis data is summarized and interpreted according to predetermined themes or questions or dimensions used in interview and observation process. Obtained data according to the pre-formed frame is read and edited (Yıldırım & Şimşek, 2000). In this study the data has been summarized and interpreted considering the activity steps. For this, the data has been regulated according to the mentioning situation of themes (models, inference, creativity and imagination, etc.) belonging to each steps in the data sources. Descriptive analysis often includes direct quotations for reflecting the views of students interviewed or observed conspicuously. The purpose of such analysis is to provide findings as obtained and interpreted to readers (Yıldırım & Şimşek, 2000). In this research the roles of students and teacher have been explained and the quotes of students' views have been given for each steps.

The Magnetic Field Lines Activity and Its Implementation

1st Step: The aim of this step is to find out about the foreknowledge of the students on scientific models. For this purpose, the students were asked "What do scientific models do?" and the activity started. Some of the answers from the students were as follows;

Student 1: *"We learn about the subject, they enable us to come closer to the truth."*

Student 3: *"They keep us informed."*

Student 4: *"They enable us to come closer to the truth."*

The researcher listened to the conversations between the students and gave no information. All of the students were given time to answer the question. But initially, some of the students only agreed with their friends who answered the question.

2nd Step: The aim of this step is to find out about the concepts of observation and inference, and make up the deficiencies. For this purpose, a bar magnet, whose poles were hidden by wrapping it with paper, was shown to the students and then it was placed on a glass plate and a small amount of iron powder was sprinkled (Figure 1). The students were asked to explain what they saw about the distribution of the iron powder. Some of the students' statements were as follows:

Student 1: *"The iron powder has gained magnetic property."*

Student 4: *"We see that the magnetic field affects the iron powder."*

Student 1: "*The magnet's tensile strength is not the same everywhere, it is stronger on the poles.*"

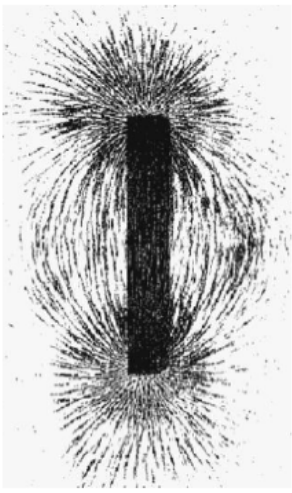

Figure 1. *Distribution of the iron powder around a bar magnet, whose poles were hidden*

The students were encouraged to discuss about the shape formed by the iron powder and the reason behind it and questions were asked when necessary. A part of the conversation between the students and the teacher was as follows:

Teacher: *"Can you see the magnetic field?"*
Student 3: *"I can see the polarization of the iron powder."*
Teacher: *"What causes this polarization?"*
Student 3: *"The magnet has two different poles, and the strength of the magnetic field around it is different."*

It was explained to the students that the explanations, which they made, was based on their foreknowledge.

3rd Step: The aim of this step is to get the students to make a drawing, which is to be used in the 5th step. The students were asked to make a simple drawing of the observations which they made in the previous step. The drawings of the students were collected and the next step was initiated.

4th Step: The aim of this step is to explain that scientists use their creativity and imaginations to explain natural events and the subjective nature of scientific knowledge. The students were asked the question regarding Figure 1 "Do you have an observation about the magnetic field starts from which pole and goes to which pole?" All the students answered that the poles of the magnet cannot be observed based on the distribution of the iron powder. Examples of the answers:

Student 2: *"We can't observe it based on this."*
Student 4: *"Both poles pull, so we can't understand."*
Student 3: *"The poles are not known."*

Meanwhile, the experiment was repeated with a magnet, whose poles were marked (Figure 2).

Figure 2. *Distribution of the iron powder around a bar magnet, whose poles were marked*

The students were asked the question "Now can you observe the magnetic field lines starts from which pole and goes to which pole?" Based on their theoretical knowledge, the students said that the magnetic field lines outside of the magnet were from the North (N) to the South (S). Then, the students were asked the question "How do you know that the magnetic field lines are from N to S based on the formation of the iron powders?", but none of them were able to answer. Then, the students were asked the question "Is there any kind of signs (e.g. arrowhead) that show the direction of the magnetic field lines?" Some of the answers from the students were as follows:

> Student 1: *"The formation is same on both sides, there are no differences or orientations!"*
> Student 3: *"After all, it needs to move from some place to another, like current. They must have accepted as a law."*
> Student 2: *"Nothing changes even if we say it is from S to N! After all it was a necessity to determine a direction."*

Finally, the students found that the direction of the magnetic field line of the magnet was an "assumption" they. It was explained to the students that scientist had reached to the same "assumption" about the direction of the magnetic field lines based on their observations. A speech was given about the subjective nature of the scientific knowledge and that it was based on creativity and imagination.

5th Step: The aim of this step is to emphasize that scientific models are not exact copies of the truth and that the scientific knowledge is open to changes. For this purpose, the amount of iron powder on the glass plate was reduced and pointing out the distribution of the iron powder in the magnet's magnetic field, the students were asked the question "There are gaps through iron powder. Is there a magnetic field where there is no iron powder?" Some of the answers given by the students were as follows:

> Student 2: *"There is no magnetic field in the gaps."*
> Student 3 *"There is no magnetic field, because when there is, it (iron powder) denser."*
> Student 4 *"I think there is a magnetic field."*
> Student 1 *"I think there is a magnetic field; however, it is weak, not strong enough. There is magnetic field but not at the same degree, or else it (the distribution of iron powder) would be equal."*
> Student 2: *"If there was a magnetic field, it would distribute equally."*
> Student 4 *"I don't think there is. That's why they distributed like this (like the iron powder on the glass plate)."*

The students started to discuss about the subjects among themselves. The researcher waited until students reached certain opinions such as "there is" or "there is not" and didn't intervene in order to direct them. Then, the students were asked to increase the amount of iron powder on the glass plate. The students eagerly sprinkled iron powder on the glass plate and examined the resulting pattern. Some of the statements from the students were as follows:

> Student 3: *"But if we put too much, the number of gaps will reduce anyway."*
> Student 2: *"So there is a magnetic field after all."*

The drawings made in the 3rd step were given to the students, who understood that there was a magnetic field in the gaps among the iron powder too. They were asked the question "Why was the model which demonstrates the magnetic field drawn this way?" Since all of them demonstrated the magnetic field as lines and left gaps between the lines, they were asked: "Why did you leave gaps between the lines? Why didn't you draw it by filling between the lines by pencil? Could we demonstrate it like this in a textbook?" The students answered *"to make it easier to demonstrate"*. The students were explained that scientific model were not exact copies of the truth and that scientists used supplementary tools in order to explain natural events.

6th Step: In this step, it will be emphasized that scientific models are not exact copies of the truth, but they are simplified tools to demonstrate a natural event and they may have insufficiencies while explaining a natural event.

The magnet was placed vertically on the table and the same glass plate was placed on it. A certain amount of iron powder was sprinkled on it. The students saw the iron powder perpendicular to the plane and the orientation towards them. The students were asked: "When we look at the model that demonstrates that the magnetic field lines around the magnet, we see that it is two-dimensional. Is this model incorrect?" The students replied:

> Student 3: *"Scientists have always simplified things. For example, I can have an idea when I look at the model."*
> Student 1: *"It is not completely incorrect, it is just simplified. I could understand that there was no magnetic field in the gaps, it (the model) demonstrates it that way."*
> Student 4: *"How can it be drawn three-dimensionally! With embossing?"*

The students were asked to write down what they learned during the activity and their opinions about the activity briefly. The papers were collected and the activity was completed.

RESULTS and COMMENTS

In this section, the results obtained during the implementation of the activity will be explained. The results are based on the observations of the researcher, evaluation of the video recordings, the drawings by the students made on the 3rd step and the reflective papers written by the students at the end of the activity.

It was noted that the students were hesitant during the first step of the activity in which the ways to find out about the foreknowledge of the students on scientific models. They were hesitant to share their opinions. After they were encouraged by the researcher, the students asked what was meant with scientific models and that they were given examples. After giving examples, the students started to speak about the subject with the help of various questions. During these conversations, the students stated that scientific models were used in order to give information on a subject and understand the truth. It was found that the students had correct but limited foreknowledge about scientific models and had the mythical idea that scientific models were exact copies of the truth (McComas, 1998).

In the second step of the activity in which the difference between observation and inference was emphasized, the students were asked to explain the reason behind the distribution of the iron powder. Since knowing the difference between observation and inference forms a basis for higher level skills, it refers to as a basic process skill (Abruscato, 1996; Martin, Sexton & Gerlovic, 2002). In this step, the students explained the incident and its reasons without using the words "observation" and "inference", which were the words the researcher was expecting to see. Since the students knew the concept, but were not able to name it, the researcher explained that the activity committed in order to research or understand an incident was referred to as "observation", and the knowledge, which is compatible with the data, obtained as a result of this observation was referred to as "inference". It was seen that the students made the connections between many elements of the nature of science by themselves during the activities (Meichtry, 1992). To make it possible for students to realize these connections, they were given explanations about observation and inference as well as explicit-reflective discussions.

Some of the drawings made by the students in the third step of the activity, in which they were expected to draw a natural event by simplifying it, are shown below.

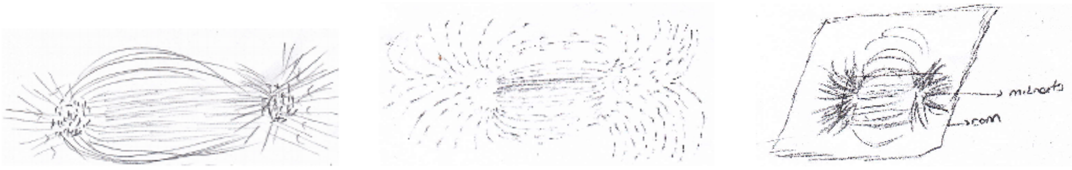

Figure 3. *Examples from the drawings of the students*

Examining these drawings, it is seen that two of the students tried to draw the natural event exactly, while the other three paid attention that the lines did not cross each other, paid attention to the density of the lines as they saw in the textbooks, and they even added arrows that show the direction of the magnetic field, which they did not observe but knew theoretically. A discussion about these steps was carried out by the students in the fifth step.

The students were surprised by the fact that they were not able to observe the direction of the magnetic field line even though they were confident in their theoretical knowledge of the subject during the experiment in the fourth step, in which it was aimed to emphasize the subjective nature of the scientific knowledge and that it was based on creativity and imagination. According to the literature, students believe that the scientific knowledge is complete and absolute (BouJaoude, 1996; Çelikdemir, 2006) and that the correctness of the theories is proven as experimental evidence is collected (Smith, Maclin, Houghton & Hennessey, 2000). In this step, when the students reached the conclusion that the direction of the magnetic field was an “assumption”, they confessed that they had never considered how this information had been obtained. It has been reported in the studies in the literature that students couldn’t understand the importance of creativity and imagination in the production of scientific knowledge (Abd-El-Khalick & Boujaoude, 1997; Aikenhead & Ryan, 1992; Griffiths & Barman, 1995).

It was noted that the students were enthusiastic during the fifth and sixth steps of the activity. The students expressed their opinions more comfortably and participated in discussion willingly. For example, it was observed that the students tried to convince each other about whether there was a magnetic field in the gaps during the discussion on their drawings which they made in the third step and defended their opinions. At this point, it can be said that the students understood what was trying to be done in this activity. The students who claimed that there was no magnetic field in the gaps thought that the models were exact copies of the truth, as stated in the studies in the literature. (Abd-El-Khalick, 2002; Aikenhead & Ryan, 1992; Grosslight, Unger, Jay & Smith, 1991; Lederman & Abd-El-Khalick, 1998). In the first step, it was stated that the students did not hold the mythical opinion that scientific models were exact copies of the truth. However; in this step, it was seen that they held this opinion. In the fifth step, the students, who had a discussion about whether there was a magnetic field between magnetic field lines in the model demonstrating the magnetic field lines around a magnet, accepted that there was a magnetic field with the help of observations after increasing the amount of iron powder. In the meantime, conversations were made by the students on the model which they drew in the third step. In the sixth step, the conversation about the three-dimensional property of the magnetic field continued. As a result of these steps, it was seen that there was a development of the students’ ideas about scientific models. It was found that the students made more realistic comments on the drawings in the textbooks which demonstrate the magnetic field.

Once the activity is completed, examining “the reflective papers” written by the students on their opinions about the activity or what they learned during the activity, it was noted that all of the students started the papers with definitions of observation and inference. The reason behind this may be the fact that they struggled with naming these concepts during the implementation. Some of these opinions are as follows:

"Observation means making a research about an incident. Inference is the knowledge we find after observations." (Student 1)

"Observation: Forming certain ideas about an incident. Inference: Conclusion which can be reached from these ideas." (Student 3)

Then they mentioned basic properties such as scientific models didn't contain certain properties of the natural event deliberately and were not exact copies of the truth. Some of these opinions are as follows:

"Scientific models don't reflect the truth completely." (Student 3)

"We know that magnetic field lines are three-dimensional, but we learned that they are drawn two-dimensionally." (Student 4)

"(...) we saw that from N to S was an assumption and I learned that there were lines between magnetic lines." (Student 5)

Based on these facts, it can be said that the pilot activity was successful in terms of improving students' understandings of changeability of scientific knowledge, its empirical nature, its subjective nature, its partly being a product of creativity and imagination, the difference between observation and inference.

SUGGESTIONS

Each step of the activity aimed to get the students think like a scientist and thus, the stages of formation of the scientific knowledge were shown to the students. Problems caused by the attitudes of the students didn't occur during the implementation of the activity. The reason for this may be the small number of students. There may be problems about the participation of students in more crowded classes. However, it shouldn't be ignored that with the increased number of students, there will be a large variety of opinions and a richer discussion environment during the implementation of the activity.

Brickhouse et al. (2000) has stated that the chosen subject context was important. In this study, the subjects of "Magnetism" and "Electromagnetic Induction", which are the first two subjects of 12th grade physics class, were chosen as the subjects of the activity. The first reason was that these two subjects were reported to be the ones with which the students struggled most (Aycan & Yumuşak, 2002). Another reason was that the rich content of the subjects of Magnetism and Induction -such as many scientists' working on this subject with or without knowing about each other- in terms of the history of science, which started with Oersted and gained momentum with Faraday. Irwin (2000) suggests that explaining the historical development of subjects with examples while teaching science classes may encourage students to learn about the nature of science. It was thought that elements of the nature of science could be taught to students by giving examples from the history of science and enriching discussions.

It is more suitable to teach the nature of science by spreading it throughout the curriculum instead of teaching it as a separate unit (Türkmen & Bonnstetter, 1998). The fact that the students learned about the elements of the nature of science by associating them with magnetism shows that Abd-El-Khalick (2002), Brickhouse et al. (2000), Ryder et al. (1999), Khisfe (2004), Khisfe and Abd-El-Khalick (2002), Khisfe and Lederman (2007) were right about their suggestion of teaching the nature of science based on a subject area. It is thought that students will understand the elements of the nature of science better and learn the subject better when they are exposed to activities about the nature of science throughout the subjects

Khisfhe and Abd-El-Khalick (2002) has found that teaching the nature of science made it possible for students to understand science i.e. the subject area better. However, it was not measured how beneficial the study was in terms of teaching the students the subject area. It is recommended to researchers to conduct studies in which both the gains in terms of the nature of science and in terms of the subject area can be measured after the activity is designed and implemented.

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