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INVESTIGATING THE EFFECT OF NATURE OF SCIENCE ACTIVITIES ON PRE-SERVICE SCIENCE TEACHERS' CRITICAL THINKING SKILLS

(Fen Bilgisi Öğretmen Adaylarının Eleştirel Düşünme Becerileri Üzerine Bilimin Doğası Uygulamalarının Etkisi)

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Abstract

This study aims to investigate how nature of science activities affects pre-service science teachers' critical thinking skills. The participants of this study are 62 pre service science teachers; 47 of which are girls and 15 are boys. Motivated Strategies for Learning Questionnaire (MSLQ), developed by Pintrich, Garcia, and McKeachie (1991), was used to assess students' critical thinking skills for both pre-test and post-test. Real Fossils, Real Science, Tangram, Flojiston, The Tube, The Cans were activities that used in the present study to discuss nature of science. During the discussions, pre-service science teachers were encouraged about to dwell on the common misconceptions about the nature of science. A one- way within-subjects ANOVA test was conducted to compare pre-test and post-test results about students' critical thinking skills. According to the results, there was a significant difference between pre-test and post-test. In other words, the results suggested that the nature of science activities is effective to improve pre-service science teachers' critical thinking skills.

Keyword: Nature of Science, Critical Thinking, Activities

Özet

Bu araştırma, Fen Bilgisi Öğretmen adaylarına uygulanan bilimin doğasına yönelik etkinliklerin, eleştirel düşünme becerilerine etkisini ortaya çıkarmayı amaçlamaktadır. Araştırmanın uygulama grubunu, 47 bayan ve 15 erkek olmak üzere toplam 62 öğretmen adayı oluşturmaktadır. Veri toplama aracı olarak, 1991 yılında Pintrich, Garcia, and McKeachie tarafından geliştirilen "Öğrenmede Güdüsel Stratejiler" anketinin eleştirel düşünme boyutu kullanılmıştır. Bilimin doğası etkinlikleri; Gerçek fosiller, Gerçek bilim, Tangram, Flojiston, Kutu ve Bileşik Kaplar gibi etkinliklerden oluşmaktadır. Öğretmen adaylarının eleştiriyel düşünme ölçeğine ait ön test ve son test puanları arasındaki ilişki ANOVA testi ile değerlendirilmiştir. Analiz sonuçlarına göre eleştirel düşünme ölçeği öntest ve son test sonuçları arasında anlamlı farklılık tespit edilmiştir. Diğer bir deyişle, bilimin doğasına yönelik etkinliklerin öğretmen adaylarının eleştiriyel düşünme becerileri üzerinde olumlu etkiler oluşturduğu sonucu çıkartılabilir.

Anahtar Kelimeler: Bilimin Doğası, Eleştirel Düşünme, Etkinlikler.

Introduction

One of the missions of Education Faculties is to help prepare outstanding educators through research on the science and art of teaching and learning, since, it is a way both to offer advantages of science to society, and to raise children with necessary knowledge and skills. For instance, in today's world, presence of individuals who have critical thinking skills become much important to offer different solutions to problems, and make healthy decisions. Critical thinking is a self-regulatory decision making mechanism that depends on interpretation, analysis, evaluation and deduction of the methodological or contextual investigations. Although critical thinking is not the synonym of the good thinking, it mostly forces to make criticisms and help people to become better (Facione, 1990). Critical thinking can also be defined as getting to know different point of views, interpreting the society and its elements in a rational and analytical manner in order to understand the world better (Delaney, 2007; Serafini, 2007). Moreover, the relevant researches suggest that critical thinking skills also effects students' learning. According to the researchers, critical thinking makes students not only be aware of their learning process, but it also helps students' metacognitive strategies. Additionally, it effects students' achievement (Adams et al., 1999; Ip, et. al, 2000). Therefore, the studies suggest that critical thinking should be included into education programs (Bakioğlu &Hesapçıoğlu, 1997; Costa & Lowery, 1989; Feuerstein, 1999; Gadzella et al., 1996; Ip and et all, 2000; Paul, 1984).

Classrooms where students can freely express and analyze their ideas in a systematic manner have positive effects on developing critical thinking skills. Teachers who follow critical thinking methods lead their students towards finding different options and searching for different points to support their ideas (Patrick, 1986; Bowman, 1987). According to Evancho (2000), a teacher-oriented school prevents the development of creativity and critical thinking skills due to the fact that the teaching method would be based on memorizing. In order for creativity and critical thinking skills to develop it is important to follow methods that are based on habits and qualifications (Evancho, 2000: 22). Potts (1994) studies methods that can be used for teaching of critical thinking and he suggests several different methods. The suggestions he makes are as follows as stated in his work named "Methods for Teaching of Critical Thinking": "Providing the means for students to do a research on the given preliminary information while solving a problem and deciding whether the information is necessary and applicable or not, asking for different ways of solutions to the problems, improving the communication between the students". Furthermore, asking questions which are open-ended, giving enough time to students for them to answer questions and asking students to use what they have learnt in several different occasions also help in teaching of critical thinking.

Nature of Science

One of the main aims of science and technology education is to raise individuals with scientific literacy; for this to happen the main component related is the nature of science. It is necessary for nature of science being understood well in teaching of all branches of sciences, natural science being the prior branch. Institutional and personal decisions are mostly based on scientific data, or at least expected to be so. For these decisions to be healthy and reasonable it is very important to understand the nature of science (Çelik and Bayrakçeken, 2006; Flick and Lederman, 2004; Lederman et al. 2002).

In order to fully understand the main aspects of nature of science students should first be able to give personal and common decisions with the help of scientific information; they should also deeply understand how scientific information is structured in order to understand the source as well as the borders and limits of the information they have. The teachings on the nature of science constitute the basic critical element of science-technology-society understanding, which is a dimension of scientific mind (Lederman, 2004).

Nature of science brings different disciplines together such as history of science, psychology of science, philosophy of science, and consists of answers to questions like; (McComas ve Olson, 2000).

"What is science and how does it proceed? How does scientist work?

How does social and cultural context affect science?"

It is hard to assign one specific definition to nature of science since science is multi-dimensional, complicated and dynamic. For the same reason what is meant by the term "nature of science" is a subject of discussion for science philosophers; there is not one specific definition of nature of science which is generally accepted by all authorities (Abd-El-Khalick & Lederman, 2000). Generally what is meant by nature of science refers o concept epistemology of science; the values and beliefs that embody the path to the development of scientific information (Lederman, 1992). McComas and Olson (2000) state that nature of science brings different disciplines together such as history of science, psychology of science, philosophy of science, and analyzes questions like "What is science and how does it proceed? How does scientist work? How does social and cultural context affect science?

Scientific theories and scientific models are not facts discovered with just observation and experiments; rather they are information structured by scientists based on observations and experiments. With this assumption observations and experiments do not constitute the basis of science; they are side elements that support coming up with arguments in order to reason scientific ideas. The distinctive characteristic of science that separates it from other disciplines is the way it reasons the ideas and it uses rational methods like argumentation and scientific thinking (Siegel, 1989). Many students, even teachers, have difficulties about understanding nature of science. Besides that, this understanding doesn't come naturally with maturity. Therefore it is important to teach both students and teachers the aspects of nature of science such as the distinction between observation and inference, that scientific knowledge is partly a product of human inference, imagination, and creativity, that scientific knowledge is, eventually, empirically based, that scientific knowledge (both theories and laws) is tentative and subject to change, and that science is culturally and socially embedded (Lederman& Abd- El- Khalick, 1998). For an individual to understand the nature of science he should have some basic thinking skills.Specifically, reasoning an idea and coming up with arguments requires thinking skills. There are a number of thinking skills defined; but critical thinking raises higher when it comes to effective learning and effective teaching (Balcaen, 2011; Tall, 2004). Therefore, the present study aims to investigate the relation between nature of science and critical thinking skills. In relation to this, the following research question was addressed to answer. Is there a significant difference between pre-service science teachers' critical thinking skill before and after attending to nature of science activities?

Method

Sample

There were 47 (76 %) female and 15 (24 %) male, 3th grade pre-service science teachers participating in the study. They were coming from families with mostly 2 children. Although the majority of the students' mothers were unemployed (66 %), the majority of the students' fathers were employed (58. %). The majority of the students' mothers graduated from primary education (59. 7%), while, the majority of the students' fathers graduated from high school (27. 4%). There are exiguous reading materials, fewer than 100 at most students' homes (59. 7%).

Instruments

Motivated Strategies for Learning Questionnaire (MSLQ)

It is a self-reported questionnaire developed by Pintrich, Garcia, and McKeachie (1991). Students rate themselves on a seven point Likert scale from "not at all true of me" to very true of me" concerning different aspects of their learning and motivational strategies. One of the sub-scale of MSLQ is critical thinking. It assesses critical thinking with five items like "*Whenever I read or hear an assertion or conclusion in science class, I think about possible alternatives*", or "*When a theory, interpretation, or conclusion is presented in a science class or in the readings, I try to decide if there is good supporting evidence."* The MSLQ translated and adapted in to Turkish by Sungur (2004). In this study, the MSLQ was used to assess pre-service science teachers' critical thinking. The reliability coefficients were .82 for the pre-test, .84 for the post test.

The Treatment

Activities that Used to Teach Nature of Science

There is a required course, named "*Nature of Science*", in the Science Teacher Education program in Turkey. Third grade students attend this course at the spring semester. There were 62 students enrolled this course at the 2012- 2013 academic year. The lesson emphasizes nature of science with interesting activities. The following activities were conducted during 2012- 2013 academic year:

The Mystery Fossil Bones

This activity taken from Krech's (2008) work. In this activity, students work with the fossil fragments like paleobiologists.

The process

This was a team work study. There were 5-6 students in each of the group. The instructor gave each pair of students the same fossil fragments (not all of them) and asked them to trace the outer perimeter of their fossil fragment diagrams and make predictions about the organism. Additionally, the groups were told that they are responsible to make a short presentation about their predictions.

Materials

The figure 1 represents the creature and the bones that are given to the groups. The creature was shown the groups at the end of the activity.

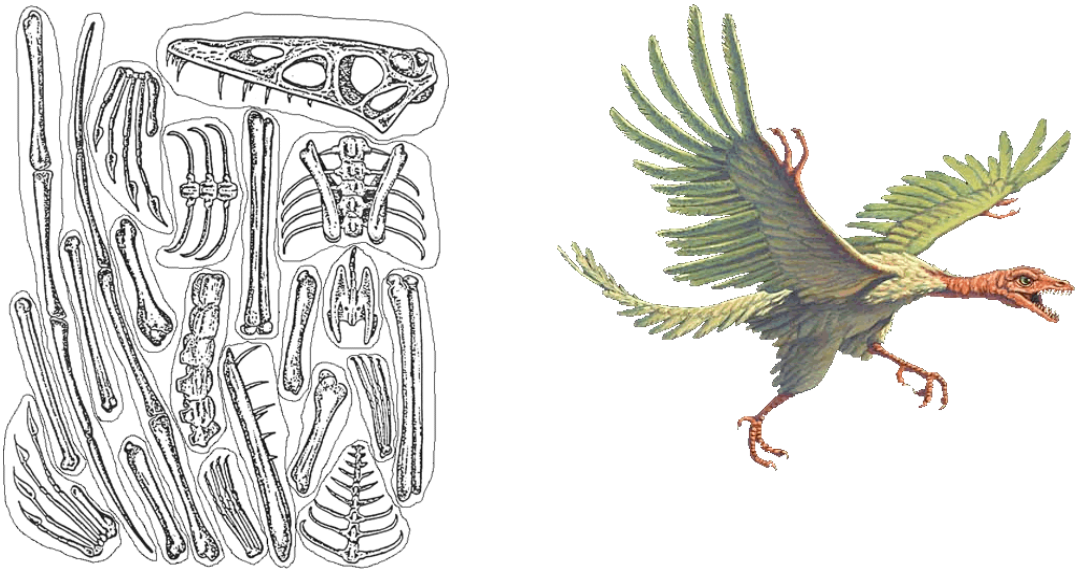


Figure 1. The Organism and its Fossil Fragments

Time

1 and half hours

At the discussion

At the end of the activity, each pair of students made oral presentations about what they figured the organism and they compare their prediction with the others. It was interesting for them to see each pair of students make different inferences from similar fossil fragments.

Tangram

This activity was adapted from Doğan and her colleagues (2010).

The process

This was a team work. There were 2 students in the each of the group. In this activity, each group of students was given 6 pieces of tangram. They asked to make the presented figure, see also figure 2, with the pieces of tangram. After they complete the figure, the last piece of tangram was given, and asked the groups of students to make the same figure with the 7 piece of tangram.

Figure 2. The human figure

Materials

Tangram pieces

Time

1 hour

At the discussion

Students told that the last piece represents a new scientific data so that you need to consider new data when you make a research. This activity helps students to understand that science is culturally and socially embedded, and tentative.

Phlogiston

This activity was taken from Doğan and her colleagues (2010).

The process

Phlogiston was a theory that had been accepted to explain combustion until the theory of oxygen was offered. In this activity, participants were asked to discuss these theories; phlogiston theory versus oxygen theory. There were two groups in the class. One group represented the phlogiston theory; the other group represented oxygen theory. There were relevant resources to investigate these theories in the class. After investigation section, each group defends their own theory to other group members.

Materials

Source book

Internet

Time

2 hours

At the discussion

At the end of the activity, the discussion was connected with the following aspects of nature of science; scientific knowledge is partly a product of human inference, imagination, and creativity. Scientific knowledge is, eventually, empirically based (i.e., based on and/or derived from experiment and observation), and scientific knowledge (both theories and laws) is tentative and subject to change

The Tube

This activity was taken from Lederman and Abd-El-Khalick (2002).

The process

This was a team work study. There were 5-6 students in each of the group. The instructor made a tube like seen in figure 3 before the class. In this non-transparent tube, there is a mechanism that when you pull the rope in right and top, the rope in the left and bottom moves or vice versa. Students were asked to predict the mechanism in the tube and each group presented their prediction.

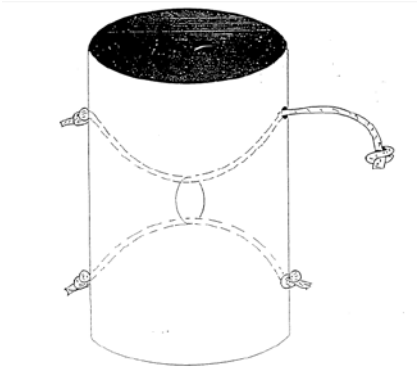


Figure 3. The tube

Materials

Cardboard

Ring

Rope

Time

1 and half hour

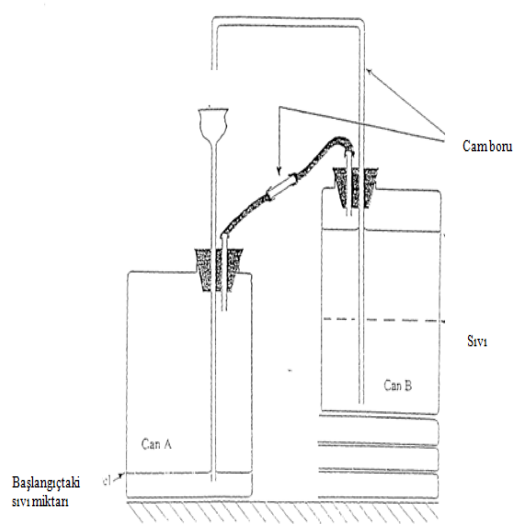
At the discussion

At the end of the activity, they realize that they don't have same predictions. The discussion was enriched with the following subjects; scientific knowledge is partly a product of human inference, imagination, and creativity. Scientific knowledge is, eventually, empirically based (i.e., based on and/or derived from experiment and observation), and scientific knowledge (both theories and laws) is tentative and subject to change.

The Cans

This activity was taken from Lederman and Abd-El-Khalick (1998).

The process



This was a team work study. There were 4-5 students in each of the group. For the activity, the instructor prepared the system like presented figure 4 before the class. There is water in the can A, and colored water in the can B. The initial levels of liquid in cans A & B appear in Figure 4. Using a beaker, pouring enough starts pouring into the funnel from the glass tubing above. The water keeps running for a long time. The cans appeared like a closed system.

Figure 4. There is water in the cans.

Students were asked to make observations, collect data, draw inferences, and suggest hypotheses and test their hypothesis about how this closed system works. Moreover, each group made a short presentation about their prediction.

Materials

2 500-mL Erlenmeyer

flasks wrapped with aluminum foil),

2 rubber stoppers, rubber tubing,

I thistle funnel,

glass tubing, (optional: ethyl alcohol, iodine, food coloring)

time

1 and half hour

At the discussion

The instructor made a discussion about the following aspects of nature of science; the distinction between observation and inference, that scientific knowledge is partly a product of human inference, imagination, and creativity, and that scientific knowledge is, eventually, empirically based (i.e., based on and/or derived from experiment and observation)

Results

Descriptive Statistics

Descriptive statistics were used to investigate the pre-service science teachers' profiles about critical thinking skills. Table 1 presents means and standard deviations for pre-test and post-test.

Table 1. Means and standard deviations for pre-test and post-test of critical thinking.

	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	62	2.20	7.00	4.97	.86
Post-test	62	3.60	7.00	5.34	.84

Inferential Statistics

A one- way within-subjects ANOVA test was conducted to evaluate whether the nature of science activities is effective to improve pre-service science teachers' critical thinking skills. The results indicated that the mean for critical thinking skills after the activities (M= 5. 34, SD= .84) was significantly higher than skills before the activities (M= 4. 97, SD= .86). Wilks $\lambda = .87$, $F(1, 62) = 8.77$, $p=.004$ $\eta^2 = .13$.

Discussion

The present study aimed to investigate the effect of nature of science activities on pre-service science teachers' critical thinking. According to the results, the nature of science activities make students' improve critical thinking skills. Actually, this was an expected result since the relevant literature suggests that critical thing is a form of scientific method, so that teaching nature of science can affect these skills (Belenky et al. 1986; Baxter Magolda 1992; King& Kitchner 1994). In a similar study, Can and Pekmezci (2010) investigated the effect of nature of science activities on students' scientific process skills in middle school students. Sixty, 7th grade students participated in the study. The activities were chosen to teach nature of science in middle school level. According to the results, there was a significant difference between control and experiment group.

The activities that conducted in the nature of science lesson with pre-service science teachers have a common feature: all of them force to students think a different way. They were encouraged to share their ideas freely, since nature of science activities include the basic concepts of critical thinking like suspiciousness, criticizing and analyzing. For instance, in the cans activity, pre-service science teachers were supposed to make observations, collect data, draw inferences, suggest hypotheses, and explain both rightness and mistakes of their hypotheses to their peers after they test the hypotheses. During the explanation, the whole class was included to the discussion. They criticized the presenters and made suggestions. Actually, the other activities also include discussions, criticisms and suggestions. Moreover, all the participants should have used scientific process skills while conducting to the activities. Critical thinking is also seen a part of scientific method (Belenky et al. 1986; Baxter Magolda, 1992) and correlated with scientific process skills (Yahsi& Kahraman, 2013), so it is not surprised that nature of science activities help to improve critical thinking skills.

There are some limitations in this study. Firstly, this study was only conducted 3th grade pre-service science teachers. Therefore the results of the study cannot be generalized all of the students. For example, it

may be different in high school students. Secondly, this is a quantitative study. In the future, other studies can use quantitative and qualitative studies together, to make in depth investigate the mentioned relationship. For the follow up study, students can be forced to create activities to teach nature of science.

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