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How to Teach the Nature of Science for Student Science Teachers?

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Abstract

This study aims to investigate the influence of History of Science Cases on student science teachers' (SSTs) nature of science concepts. This study was used as a qualitative research method. For this study, History of Science Cases were implemented for a group of 18 SSTs. Data gathered via-nature of science questionnaire and semi-structured interviews. In addition, SSTs wrote reflective notes after their each activity. It was concluded that SSTs had naive views about the aspects of the NOS at the beginning, however, they had informed views about it after the intervention especially in four aspects; Tentative and empirical relationships between scientific theories and laws, the role of social and cultural context in science, creative nature of scientific knowledge and difference between an observation and inference. It is suggested, supporting previous work in that developing informed conceptions of the NOS for SST is a cognitive instructional outcome that requires History of Science Cases.

Key Words: Nature of scince, history of science cases, student science teacher

Introduction

It is a certainty that science affects society in many aspects and is very important in human life. In order to provide community with scientific thinking, science should be a common value of society. Today, understanding science and its aspects is one of the core aims of many educational attempts in the world. One of the most important purposes of these educational attempts is to train Scientifically Literate individuals (Sevim, 2007; Sevim, 2012). Scientifically literate individuals are the ones who make research, argue, try, observe, increase their knowledge constantly, and besides, develop scientific approaches. One of the prerequisites to be a scientifically literate is to understand the nature of science. Knowing nature of science might provide a frame to evaluate and to criticize science issues of newspaper and journal article, news on TV and formal explanations provided by states. Therefore, nature of science understanding might contribute more democratic and scientifically literate society as entities for prosperous society and personal lives.

Although no agreement exists for a specific definition of NOS among science historian, philosopher and educators, they have the same opinion about aspects of the nature of science. These

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aspects have been emphasized in recent reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996) and include understanding that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of natural world), subjective (influenced by scientists' background and experiences), partly the product of human imagination and creativity (involves invention of explanations), socially and culturally embedded, the differences between observations and inferences (scientific knowledge is partly a function of each), and the relationships between scientific theories and laws.

However, research has shown that student teachers' and teachers' understandings about NOS are frequently inconsistent with current conceptions (Abd-El-Khalick & Lederman, 2000; Akerson & Abd-El-Khalick, 2000; Akerson & Hanuscin, 2007; Bianchini & Colburn, 2000; Carey et al., 1989; Fishwild, 2005; Khishfe & Abd-El-Khalick, 2002; Irwin, 2000; Khishfe, 2008; Küçük, 2006; Lederman, 1999; Lederman et al, 1998; McDonald, 2008; Sevim & Pekbay, 2012). If teachers hold naive views of NOS then they will almost certainly pass these beliefs onto students. Therefore, a necessary step in improving instruction and students' conceptions related to the nature of science involves first addressing teachers' conceptions of NOS. There have been numerous attempts to enhance learners' views of NOS (Driver et al., 1996; Hogan, 2000; Lederman & Abd-El-Khalick, 1998; Lederman, 1992; Reif & Larkin, 1991). These attempts can be categorized under three general approaches: (a) explicit-reflective, (b) implicit and (c) historical approach (Abd-El-Khalick, 2001; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El- Khalick, 2002).

In historical approach, the aim is to provide students' participation to the activities in which they can discover the developments of scientific theories in social and cultural context during that time period. It is seen that studies on the effects of historical approach on the students' understandings of NOS, have conflicting results. In the study carried by Solomon and friends, historical approach is defined fairly well and it is found that, by this approach, students' understandings, particularly of scientific thoughts are temporary, has developed. Whereas Klopfer and Cooley (1963) and Solomon ans his collegues (1992) reported favorable changes in learners' views, Welch and Walberg (1972) reported that historically oriented science instruction failed to influence students' conceptions of NOS favorably.

The other reason to use historical perspective in teaching the nature of science in this study is the suitability of teaching nature of science with the history of science.

Method

The present study interpretive in nature (Strauss and Corbin, 1990) and focuses on the meanings that SSTs ascribed to the emphasized NOS aspects. The data collection was continuous and spanned nearly a three months period in which SSTs were enrolled in the NOS lesson in 2011-2012 academic years.

Sample

One cohort of Turkish SSTs was investigated by this study. 18 undergraduate students (12 male and 6 female Turkish fellow citizens) were enrolled in NOS course during the spring 2012 semester. The SSTs' ages ranged between 20 and 26 years, with a median of 22 years. These SSTs were seeking a bachelor's degree in elementary education to become a science teacher. The cohort was in their sixth semesters of their teacher development program which dues completely eight semesters.

Context of the Study

NOS course was a three-credit/hours optional course. The classes were held weekly in three-hour blocks throughout the three-month period. The course aimed at helping SSTs develop deeper understandings of NOS aspects. SSTs were encouraged to teach the nature of science with historical approach. In this study, to research and argument, scientific developments of different cultures during different time periods are selected for students...Headlines are set as; science in Early Times, science in Ancient India, Science in Ancient Europe, Science in Ancient Egypt, Science in Ancient Greece,

Science in Islamic Period, Science in 20th Century, and Science in 21st Century. The aim in this study is to make SSTs analyze the history of science from different angles: different civilizations and different scientific progresses of these civilizations. In this pattern, separating different groups, SSTs in each group, by oneself, were claimed to analyze the civilizations of in which historical process approach they will display about the science in, and were claimed to prepare an investigation report. In addition to this, it was given information to SSTs; which method they would follow in the second week of the method application, which subjects they were required to put in their investigation reports and especially in deciding how they would reply some questions about the scientist whom they searched. After they are given two weeks to complete their works, they are encouraged to present their works in each lesson beginning from third week. In this process, especially some points were implied by academic staff and these points were analyzed more comprehensively. In this way, SSTs were encouraged to experience about the living in of civilizations in different times, perspectives on the science and what changing process, information and theories were exposed to.

Instrument

The ten-item open-ended questionnaire used in the present study was previously used and validated by Lederman et al, (2002). Sixteen-item close- ended questionnaire used in the present study was previously used and validated by Küçük (2006). The data was collected within three months in which the study was conducted. The data were collected using an open-ended questionnaire, "Views of the Nature of Science- Form C (VNOS-C)" (Lederman et al., 2002) and "Views of the Nature of Scientific Knowledge" (Küçük, 2006). These questionnaires were used to evaluate SSTs' views of the NOS prior to and at the end of the study. The researcher, who was also responsible for the implementation phase of the teaching activities, also conducted semi-structured interviews with students enrolled in the course prior to and at the conclusion of the study. Interview findings were used to explore the validity of SSTs' responses to the questionnaire items. The SSTs were provided with their pre/post instruction questionnaires during these interviews and asked to explain and elaborate on their responses. This method was used in several studies to assess subjects' views related to NOS (Akerson et al., 2000; Akerson et al., 2006; Matkins et al., 2002). The interviews also aimed to generate in-depth profiles of SSTs' NOS views. The interviews all lasted about 30 minutes and were audiotaped and transcribed for analysis.

Data Analysis

In this study based on the VNOS-C questionnaires and corresponding interviews SSTs' pre-post profiles was constructed and compared. In this process "constant comparative analysis" method was used and each SSTs' views of the seven emphasized aspects of NOS were categorized into "adequate", "variable" and "naive". For example, if a participant responded that *"scientific theories change because there might be new evidence collected"* or *"theories change because of new evidence or reinterpretation of old evidence"* the response was coded as "adequate" view of tentative nature of scientific theories. If the participant responded that "theories will never change" then the response was coded as "naive" view of tentative nature of scientific theories. While participant produced adequate views some items, they didn't produce adequate views all of the items as "variable" view of tentative nature of scientific theories. It was essential to compare pre-post profiles of SSTs to decide changes in their NOS views.

Results

Tentative and Empirical NOS

Table 1. SSTs' pre-post test about tentative NOS

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	f	%
Tentative NOS	A	1	6	8	44
	V	2	11	10	56
	P	15	83	-	-

Table 2. SSTs' pre-post test about empirical NOS

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	f	%
Empirical NOS	A	10	56	14	78
	V	8	44	4	22
	P	-	-	-	-

At the beginning of the study the majority (94%) of the SSTs had inadequate views of the subjective and tentative NOS. All of them believed that the science isn't able to change, because they were sure that the science must be based on the truth. Influence the difference between the theory and the law. The most of them were sure that a theory is able to change and turn to a law, if it can be proved. While the law, how this SSTs thought, is never be able to change. A second point almost all of them recognized that the empirical NOS sets science apart from other disciplines. They explained that experiments are conducted in science however, not in other disciplines for example in religion, philosophy.

At the end of the study 44% of the SSTs were able to give an adequate answer about the empirical and tentative NOS. They recognized that scientific knowledge is able to chance, if new and better evidence will be obtained. This chance in the viewing of the SSTs can be better seen in response given in the survey and interview.

SST4 was giving response to question 1:

"*Science is the shape of classified information. Science was thought us like it usually takes inspiration from the religion. The things which are banned by religion, are used for searching by the science. Religion can change, science is never.*"

at the end of application, s/he gave this response to the same question:

"Science is the process in which combining experiment and ideas and revealing the truths. Science questioned its own truths. I mean in the science there is not certainty. It can change."

Question 4:After scientist improve a theory, can it ever change? Give an example.

While SST4 was giving response to question 4

'If the theories changed, it disproved or if it supported, turned to law. We are learning the theories for turning into law. If it is disproved, for us it worthless'

at the end of application, he gave this response to the same question:

"Theories can change because there isn't certainty. But it doesn't mean to uselessness. Theories are the most valid scientific info in the time they being."

Question 5: Is there any difference between scientific theory and law? Give an example.

While SST4 was giving response to question 5,

'Theories can change but laws never. If the theories are supported, becomes law. I mean, it is accepted by everyone, becomes laws. Example, gravity law there and everybody accept it, becomes certain. But evolution theory is not.

at the end of application he gave this response to the same question:
'Theories and laws are different scientific explanation. Theories compose the explanation of the scientific laws. But theories and even laws change.

While SST7 and SST9 ,- who had weak opinion about the uncertainty of science nature at the beginning of study however, at the end of study had variation opinions due to incoherence about responses of three questions in the survey,-were giving appropriate answers ,they didn't change their opinions which were at the beginning of the study about the first question.

In this way at the end of the study both two teacher candidates turned their weak opinions into changeable.

While SST7 was giving answer to question 1;

"Science is not mathematical notion but it is complex method. It can be defined as an effort for understanding and diagnosing world. Science isn't different from religion and philosophy. Because in all these field, specialists discuss and take aco. Scientist discuss about the science and a cleric discuss in his field. It has just one difference because of discussing in different subjects"

SST9 gave answer to the same question as;

"Science is an effort for understanding and being signified. It can't be very awfully correct to say that the science is wholly different form other fields. Because science contains physic ,chemistry, religion and philosophy. Each field makes progress within oneself. Not only religion but also philosophy has displayed evolution form past to now. Of course the science has."

The Creative and Imaginative NOS

Table 3. SSTs' pre-post test about creative and imaginative NOS

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	f	%
The Creative and Imaginative NOS	A	2	11	13	72
	V	6	33	5	28
	P	10	56	-	-

At the beginning of the study most of the SSTs (89%) couldn't comprehend the role of imagination and creativity in the science. The rest of them were indeed sure that scientists are using their imagination and creativity in their work. A Part of those SSTs, who were sure that the scientists are using those abilities in their work, restricted using those cognitive skills only on the building of their hypotheses or weren't able to give appropriate examples to back their ideas up.

%28 SSTs did not demonstrate adequate understandings the role of imagination and creativity in generating scientific claims. Most SSTs did not appreciate the creative work in searching patterns in data or developing models and theories. Students who believed that scientist use their creativity and imaginations, could not explain sufficiently in which part their studies and how they use those abilities. They ordinary put forward this idea without proving and giving example about it.

The change in the SSTs' views related to the visionary and creative nature of science can also be seen in answers they give during the interviews.

At the beginning of the study, while SST18, who has an uncertain opinion about the visionary and creative nature of science. For instance the 8th question:

> *"It is believed that dinosaurs existed 65 million years ago. There are two most accepted hypothesis formed by scientists in order to explain this existence. One of these hypotheses covers the idea of an enormous meteor that hit the earth and caused series of events which brought the extinction. On the other hand, the second hypothesis developed by other group of scientists shows that a major and intense volcanic eruption is responsible from the extinction. If all the scientists in both groups reach the same data and use the same data, how do these different results come up?"*

at the end of application, he gave this response to the same question:

> *"While beginning their studies, both groups present their hypothesis in accordance with their own views. Their object is to confirm these views. According to the data come out in the end, they defend their views by associating them with the data and their hypothesis."*

To question 10: Do scientist use their imagines and creativity during their work? Give an example.'

Answer was given;

> *"I do not think they use. Because scientists use certain steps while they are searching for answers for the questions which they set up. And they have to prove these steps."*

at the end of the study;

> *"Scientists use their imagination in all steps. For example, E= mc^2 is a result of Einstein's question "what if I get on a light?" and took its current position. Sometimes in the planning stage, sometimes in organization stage, sometimes when gathering information, sometimes in the conclusion stage for example an Ecological tool made of bamboo tree is a product of creativity."*

In this way, SST18 turned his variable view into adequate at the end of study.

At the beginning of the study SST6, who had weak opinion about the creative and imaginative nature of science but at the end had adequate view, gave answer to question 8 such as;

> *"For instance, a number of ideas were put forth about the big bang. After that, they united as a single thought."*

At the end of study given answer to same question;

"Different results come from the scientists' different views about events. Here, scientists develop and interpret different perspectives according to their research areas."

To question 10, given answer was:

"No, they do not use."

At the end of study;

"In my opinion scientists use their imagination and their creativity. They can be more creative while organizing a plan, or while gathering information, they can use their imagination and reach different information. After gathering information, they can use their imagination and their creativity in order to interpret that information."

In this way, participant SST6 converted his weak view to adequate at the end of study.

In conclusion of the study, a total of 72% of the SSTs exited the course with more adequate understanding the role of creativity and imagination in science. They believed that science required creativity and imagination. Even though they all explained that scientists use their imaginations and creativity, they believed that scientists mostly use those abilities while suggesting hypothesis than all the processes of in the scientific research.

Observation versus Inference

Table 4. SSTs' pre-post test about observations versus inference

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	f	%
Observation versus Inference	A	-	-	9	50
	V	3	17	6	33
	P	15	83	3	17

At the beginning of the study, in response to the question "how certain are scientists about the structure of the atom and the evidence scientists used to derive this structure", all of the SSTs reported variable and poor notions about observation and inference of NOS. SSTs believed some scientists have conducted some experiments and according to the experimental results. The most of them believed that an atom looks exactly like as a model itself. Either they had difficulties to make an adequate difference between the model and the reality.

At the conclusion of the study, 50% of the participant held adequate views of the observation versus inference. SSTs improving in their views about the nature of science based on the consequence can be seen in the given answers of the survey. While SST17, who had variable view about the nature of science based on consequence at the beginning of the study.

For example; Question 6: Generally in science books, atom is expressed as a system that composed with proton and neutron, formed with nucleus in the centre and circulating electrons around it. How can scientist be absolutely sure about the structure of atom?

"Scientist analyzed in nano dimension with current technology. They can see these process and cases in the screen thanks to computer systems and reveal that what it resembles and how it makes work with tests."

At the end of study;

"After scientist makes research, experiment and analyzing, they decided that atom composed such a system. Most of the scientists (Dalton, Bohr, Thomson, etc.) work on the structure of science and they get partially missing information and when they decide to what it resemble, they sometimes get benefit from their experience or creativity. Example, an experiment made by Thomson when applied voltage on cathode ray tube is withdrawn by positive pole, he recognized that is pushed by negative pole and he prepared the model of grape cake guessing the place of electrons and protons."

To question 7:

'Generally science books are defined the breed as having the same features. How can scientist be sure about features related with one breed?'

Given answer was such that:

"They worked on the most of the species and observed all features form structure of their body to nutrition habits. In the first, they made a simple classification and they made comprehensive classification as long as they found common features"

In this way, participant SST17 who had weak opinion became adequate at the end of study.

SST7 who had weak view about the nature of science based on the inference at the beginning of the study but had became adequate, gave answer to question 6:

"They were sure because they did enough studies. They believed its reality after they added their own information by analyzing the antecedent scientists' models and searches."

At the end of study, given answer was to same question:

"While scientists were deciding about the structure of atom, they couldn't directly observe the atom. But they did variable experiments using the scientific information in the different fields and they inferences from data they had. Example: Thomson used rays and using scientific rules he inferred that positive and negative particles could be and he found grape cake model."

To question 7 :

"Scientist classified breed according to their life conditions, habits and similarities while analyzing."

At the end of study:

"They were sure these information according to their experiment and observations they did. At the end of observations, they detected similar features and they looked for whether or not effective semen composed according to experiment."

In this way, participant SST17 who had weak view became adequate at the end of study.

The Subjective, and Social and Cultural NOS

Table 5. SSTs' pre-post test about social and cultural NOS

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	F	%
Social and Cultural NOS	A	-	-	16	89

	V	5	28	2	11
	P	13	82	-	-

Table 6. SSTs' pre-post test about subjective NOS

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	f	%
The Creative and Imaginative NOS	A	2	11	13	72
	V	6	33	5	28
	P	10	56	-	-

At the beginning of the study, all of the SSTs were not aware of the social and cultural influences on the interpretation of data. They dismissed possible influence of background knowledge and cultural background.

At the conclusion of the study, 72% of the SSTS held adequate views of the social and cultural NOS.

Variety in their view related with social and cultural nature of science can be seen from SSTs' answers during the interviews. SST13, who had weak view about social and cultural nature of science at the beginning of the study. For example, given answer to question 9: 'Is science universal or effected with social and cultural values? Give an example.'

"Science is universal. It isn't effected with community's religion views, experiences and cultures. If all communities handle same subjects, if Newton law is the same in our and other communities, if all communities reach the same perception when it is told Newton law and if it isn't change for communities, science is universal."

At the end of the study, given answer was:

"The reason of different development in community is the structure of socio cultural and system of religion. In this way, we can say that it reflects social and cultural values of science. Indians were very successful in nose operation. Because adulterous' noses are cut as a punishment, this operation is needed lot. So Indians were forerunners of plastic surgeon."

In this way, SST13 converted weak view to adequate at the end of study.

SST5 who had weak view about social and cultural nature of science at the beginning of the study but became adequate at the end, answered to question 9:

"Science is objective and because of this, it is universal."

At the end of the study:

"Science is human activity. We can not keep separate scientists from their environments. Science is activity which is effected by applying community and culture and also effects them. Cultural experience in community and community's expectations decide to be accepted that way and how science is done."

In this way, participant SST5 turned weak view into adequate at the end study.

SST9, who had weak view about social and cultural nature of science at the beginning of the study, but had variable view at the end of study, gave answer to question 9:

"Science is universal, I mean, science cross of national and cultural frontier and it isn't effected by values of social, politic, philosophy and the reasonable norms of culture in which science is produced. Example: Math is universal language. The same meaning is for all humans."

At the end of study, given answer was to the same question:

"At the beginning of science, when scientist has impartial approach and curiosity, he doesn't reflect social and cultural values. But community's view effects these works. In this situation, science reflects social and cultural values."

Relationship Between Scientific Theories and Laws

Table 7. SSTs' pre-post test about relationship between scientific theory and laws

GROUP		SSTs' Pre-test		SSTs' Post-test	
		f	%	F	%
Relationship Between Scientific Theories and Laws	A	-	-	12	67
	V	4	22	4	22
	P	14	78	2	11

All of the SSTs reported variable and poor notions about the theories and laws at the beginning of the study. Many believed in a notion that theories were simply meant to developing laws. Most students believed that with supportive experiments, theories would develop into laws. Thus, the kinds of knowledge explained by theories and laws were not different, just different in terms of the amount of "certainty" that supported each other. This led to the belief that laws were absolute and did not change because they had been "proven" and were the ultimate source of scientific knowledge:

At the final questionnaires and interviews 67% of the SSTs adopted the view that scientific theories and laws were different kinds of knowledge and that one did not develop in the other. They all were aware of the difference between the two kinds of knowledge structure; nevertheless they could not describe the meanings of those sufficiently:

Variety in SSTs' view about difference between scientific theory and law can be seen in the responses they gave to interview. SST5 who had weak view about nature of science based on inference at the beginning of the study,

To question 4: 'May a scientific theory be changed after scientist develop it? Give an example.'
At the beginning, SST5 gave such answer:

"Scientific theories are the thesis which isn't still proved. Because of unproved, I believed that they can be changed. They can be converted to law or they can be invalidated."

At the end of study:

"Theories can change because they haven't definiteness. It can change thanks to developing knowledge and technology. New info occurs in the light of old information. Something added to relativity theory. There was changing points. Like these, atom theory was changed and developed in over time."

To question 5:'is there any difference between scientific theory and scientific law. Give an example.

At the beginning of study, given answer was:

"There is difference. Theory is the knowledge that hasn't been definitely proved. However, law is the knowledge whose validity was definitely accepted by the consequence of scientists' experiment which was done again and again."

At the end of application:

"Of course. Both of them are two kind of different information. There is different between scientific theory and law. We can't put theory and law in one hierarchy. Theory is indirect definition of observed cases. We benefit from theories to describe evolution, kinetic gas theory, chromosome theory, relativity theory and natural events which we can't find with the measurement directly attempted. But laws are scientific information that composed to find answer to observable facts by direct measurements."

Thus, SST5, who had variable view at the end of study, converted to adequate by saying laws and theories are two kind of different information in question 5.

At the beginning of the study, SST12 who had weak view about the difference between scientific theory and law but had adequate at the end, gave answer to question 4 for only invalidation of theory :

"Theories can change. Because old theories can become invalid by doing experiment and observing."

At the end of application, he gave answer more detailed and more suitable for NOS to same question:

"Theories can change. Theories are the most valid information that is explained under their time condition. As in difference between technology of 200 years ago and current technology, also theories can be different between theories in the past and these theories which are analyzed again and proved with experiments under current condition.''

To question 5 :

"Of course, there is because law is the upper step of theory. It is the case that gains more validity."

At the end of application given answer is such:

"Yes, there. Both of them are different information from each other. Laws are information that is the consequence of generalization of relationships between observable facts. So the theories are expression of generalizations."

In this way, participant SST12 converted weak view to adequate at the end of the study.

Discussion

In this study, SSTs' conception about the nature of science is determined with the nature of science survey and also semi-structured interviews. Pre-service teacher's nature of science profiles are categorized as "adequate, naive and variable". This coding technique was also used on other studies similar to this study (Küçük, 2006; Khishfe, 2004).

Before intervention, most of SSTs had "naive" views about the aspects of the nature of science (tentative, subjective, creative and imaginative, social and cultural nature of science, and differences between scientific law and scientific theories) excluding the empirical nature of science. This result is in coherence with the results of the researches in which the pre-service teacher's thoughts about the nature of science were evaluated (Abd-El-Khalick & Akerson, 2004; Abd-El-Khalick et al., 1998; Sevim, 2012).

84% of the SSTs had "naive", %11 of them had "variable" views about the tentative nature of science at the beginning of the study. It is determined that almost all of the SSTs who share this view believe that the scientific knowledge is the certain truth and thus, never changes. They justified their views by saying "unless scientists are sure about something and the knowledge they asserted is accepted by everybody, it can not be accepted as a fact." In addition, while 6% of the SSTs adopted "adequate" view about the tentative nature of science at the beginning of the study, this rate was increased to 44% after activities are applied. Despite the fact that there were no SSTs who had "naive" view, more than 50% of the SSTs had "variable" views. In the current study, using historical approach while teaching the nature of science had a very little effect on developing SSTs' views about the tentative nature of science.

56% of the SSTs had "adequate" views about the empirical nature of science before intervention, this rate increased to 78%. None of the SSTs mentioned about the roles of data and evidences while constructing scientific facts at first. However, at the end of the study, they could understand that scientists produce facts by using the data they reached after their researches while producing knowledge. Even though scientists use their imagination and creativity, SSTs adopted the view that scientists should control the existing information according to new evidences.

None of the teachers had "adequate" views about the nature of science based on inference before intervention, however 50% of the SSTs adopted "adequate" views. SSTs who had an "adequate level of understanding the nature of science based on inference, claimed that because scientists can not observe an atom directly, they use their inferences to decide how it's structure can be. The same SSTs also claimed that while scientists decide the reasons of the extinction of dinosaurs, scientists use their inference.

While 11% of the SSTs had "adequate views about the creative and imaginative nature of science, at the end of the study, this rate increased to 72%. Beginning of this study, most of the SSTs thought that scientists use their imagination and creativity. On the other hand, they claimed that scientists use their creativity and imagination only at the start of the study, at all the other stages scientists had the same affect. However, by the end of the study, they understand that scientists use imagination and creativity at every stage of scientific studies better. It is considered that this situation is affected by the SSTs analyses about the different scientists living in the same time period, got different results from the same subject and preferred different methods for their studies occasionally.

Nearly all of the SSTs had "naive" and "variable" views about the social and cultural nature of science before intervention, at the end of the study 80% of the SSTs had "adequate" views about this element of the nature of science. By the end of the study the number of SSTs increased dramatically. Within the existing study, using the historical method while teaching the nature of science has been reasonably effective on developing the SSTs' views about the social and cultural nature of science. It can be said that especially, during the application stage, the SSTs' analysis about different cultures' studies on the science field was effective on this result.

By this study, none of the SSTs had "adequate view about the differences between the scientific theory and law, after activities were applied, 67% of the SSTs adopted "adequate" view. Before intervention, almost all of the SSTs thought there is a hierarchy between theory and law. They argued that scientific laws are the results of the experimentally confirmed theories. Results of the study majority of the SSTs changed their views and they understood that theories and laws are different from each other. It can be said that their researches and realizing that different laws and theories, which are the explanations of that laws, had been put forward at the different time period. Thus, it can be said that teaching the nature of science with historical approach is effective on developing SSTs' views about the difference between a scientific theory and a law.

Teaching aspects of NOS using historical approach is not effective enough to change the SSTs' views about the tentative nature of science and NOS based on inference. Because at the end of the study, on both of the aspects, approximately 50% of the SSTs kept their "naive" or "adequate" views. Furthermore, historical method provided a development from "naive" to "adequate" of the SSTs' views about the other elements of the nature of science. By the end of the study, the rate of the SSTs who had "adequate" views about these elements is varied between 72% and 90%. Thus, it is clear that the teaching activities applied throughout the three month is successful to teach only the four elements about the nature of science -there is a difference between scientific theory and a law, empirical, tentative, creative and imaginative, subjective and social and cultural nature of science but not others.

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