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Discipline Dependent Understandings of Graduate Students in Biology Education Department about the Aspects of Nature of Science

Biyoloji Eğitimi Alanı Yüksek Lisans Öğrencilerinin Bilimin Doğasına İlişkin Disipline Bağımlı Anlayışları

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Abstract

The purpose of this study was to investigate the understandings of graduate students in biology education department about the aspects of nature of science. The study was conducted with case study methodology and included four graduate students. Questionnaire of definitions and VNOS-C (Views on Nature of Science Questionnaire-C) as data collection tools were used. The results indicated that "biology education" graduate students showed misunderstandings about "tentativeness", "objectivity", "social and cultural embeddedness of scientific knowledge", "hierarchical relationship among hypothesis, theory and law", "definition of science" and" creativeness and imagination in science". In addition, the participants presented discipline-dependent understandings. In this paper, the results of the study are discussed and limitations and important points of the study are explained for further research.

Keywords: Nature of science, biology education, graduate level

Öz

Bu çalışmanın amacı, biyoloji öğretmenliği bölümünde yüksek lisans yapmakta olan öğrencilerin bilimin doğasına ilişkin anlayışlarını araştırmaktır. Araştırma bir durum çalışması olup, 4 yüksek lisans öğrencisi ile yürütülmüştür. Çalışmada, "tanımlar anketi" ve "VNOS-C", veri toplama araçları olarak kullanılmıştır. Araştırmanın sonuçları, öğrencilerin " değişebilirlik", "tarafsızlık", "bilimsel bilginin, sosyal ve kültürel yapı içinde gelişimi", "hipotez, teori ve kanun arasındaki hiyerarşik ilişki", "bilimin tanımı" ve "bilimde hayal gücü ve yaratıcılığın yeri" boyutlarına ilişkin yanlış anlayışlara sahip olduklarını göstermiştir. Ayrıca katılımcılar, disipline özgü anlayışlar sergilemişlerdir. Bu makalede, araştırmanın sonuçları tartışılacak, sınırlılıklar ve önemli noktalar, daha sonraki araştırmalar için açıklanacaktır.

Anahtar Sözcükler: Bilimin doğası, biyoloji eğitimi, yüksek lisans seviyesi

Introduction

In this century, biology as a scientific discipline became more important due to the increasing number of the studies conducted in various fields of biology such as genetics, molecular biology and other interdisciplinary fields including stem cell applications and new cure techniques for microbial diseases. Reflection of the results and advances provided by these studies became apparent in our lives. By the effects of these popularity and significance, people have become more dependent on acquiring knowledge of biology for their lives. Learning biology for daily life is studied under the title of biological literacy (BL). "BL" might be described as an educational aim that includes having "working knowledge about biology" and making informed decision by using biology knowledge, applying them into daily life situations, knowing nature of biology

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as "a way of knowing", understanding how scientists use methods and processes in research on biology and how scientists proceed in their studies, engaging in discussion about biological phenomena, seeking valid information about biology and being aware of knowledge sources about biology (Klymkowsky, Garwin-Doxas and Zeilik, 2003; Uno and Bybee, 1994; Damastesand Wandersee, 1992). One of the most important aspects of biological literacy includes teaching about the aspects of nature of biology and the aspects of nature of science (NOS) in general (Uno and Bybee, 1994; Damastesand Wandersee, 1992). The NOS has been including the aspects from scientific method to science in society. As result of epistemological and educational studies, some of the aspects are determined to be necessary to teach about nature of science in schools (McComas, 1998). The aspects of nature of science are described in table 1.

Table 1.
The Aspects of Nature of Science

	NOS Aspects
1.	Scientific knowledge is tentative
2.	There is no universally accepted one way to do science
3.	Scientific knowledge is embedded in social and cultural context
4.	Creativeness and imagination are also important to produce scientific knowledge
5.	There is no hierarchy among hypothesis, theory and law and they have different roles
6.	Scientific knowledge is based on evidence and observation
7.	Scientist is not objective when he or she begins to study, he or she has a background
8.	Science is a way of knowing

Note: The table was structured based on McComas (1998), Lederman, Abd-El-Khalick, Bell, and Schwartz (2002).

The aspects presented in Table 1 have importance in being biologically literate since informed decision making, evaluation of claims and explanations, management of scientific problems in daily life and use of scientific knowledge to produce useful means require to acquire informed NOS understandings on the aspects regarding to biology as a scientific discipline. Knowing about NOS aspects is a pre-requisite to know specific nature of biology as a component of biological literacy.

Undergraduate and graduate years are the most important periods for acquiring informed NOS understandings before actively participating to society as citizens. Especially, graduate studies and courses have been providing more authentic contexts to learn about the NOS aspects during the transition period to citizenship. In spite of this good opportunity to learn the NOS aspects, some of the studies have been showing misunderstandings of graduate students on the NOS aspects (Chang, 1995; Irez, 2006). The studies determining the misunderstandings have been conducted by using discipline-free approaches, in other words, they have focused the aspects with generic frame. But the some studies have been showing that epistemological ideas including NOS understandings vary across disciplinary contexts and level of education (Jehng et al., 1993; Paulsen and Wells, 1998). Therefore, there is a need to study on the NOS aspects by focusing a specific discipline at the level of graduate education.

Biology as a scientific discipline has its own special knowledge structure, validation ways and theories all of which require an attention to study on the NOS aspects in relation to biology by using discipline-dependent approach. Graduate courses and research period in graduate programs of biology education departments have been providing the most important context for

acquiring biological literacy via learning the NOS aspects by dealing with both biology content knowledge and studying on learning and teaching of this content knowledge. Therefore, to determine NOS understandings of graduate students in biology education departments might provide a beginning point to establish more comprehensive context to learn about the aspects of NOS. Based on the lack of the studies and importance of the graduate education context of biology education to learn and teach the NOS aspect, the purpose of this study is to determine the understandings of graduate students on the NOS aspects regarding to biology discipline in a discipline specific way.

Importance of Biological Literacy and NOS for Graduate Students in Biology Education

Learning about biology as a scientific discipline is dependent on the quality of biology education. Biology teacher education and the following graduate programs are the basic levels for developing quality in biology education. Secondary science teacher education and related graduate programs are the most important stages for improving science teaching because secondary school years are the first periods of time to meet scientific disciplines as separate titles such as physics, chemistry and biology. Secondary biology education has an important place due to the fact that there are characteristics which differentiate biology from physics and chemistry. Biology is directly related to life and increasing application areas of biology have been affecting daily lives of people. In addition, biology has a potential to show students' place in the world and their natural identity. Therefore, undergraduate and graduate years in biology teaching profession are the most basic period to improve biology education.

The education of secondary level biology teachers includes both biology courses and applications of biology content knowledge and the courses for biology teaching. After the graduation from undergraduate programs, some students prefer to go further by entering graduate-level programs which focus on science of teaching and learning on biology. The graduate students studying on biology education will be more likely researcher and teacher educator or decision authority in the system of teacher education for secondary schools. They are expected to have important characteristics and skills to research and teach biology and particularly nature of biology. To teach and improve biological literacy effectively is an important skill for biology teacher educators and graduate students as well as secondary biology teachers. In parallel, acquiring biological literacy in secondary education is also explained as the main aim in many curriculum and reform attempts on biology education (BSCS, 1993; Turkish Ministry of Education, 2007). Teaching biological literacy in classrooms includes teaching about the aspects of nature of science (NOS) for biologically literate society due to its importance in informed decision making (Uno and Bybee, 1994; Damastes and Wandersee, 1992). Although the literature has many studies on the components of scientific literacy in different fields of study, "aspects of nature of science" as an issue of informed decision making emerged and took much interest in scientific literacy studies (Lederman, 2007; Palmquist and Finley, 1997; McComas, 1998). Importance of the NOS aspects for different sides of life is presented by Lederman (2007). Table 2 presents importance of learning on nature of science.

Table 2.

Importance of learning nature of science for five aspects of life

Aspects of Life	*Explanation for Importance of Nature of Science*
Utilitarian	Understanding nature of science is necessary to manage the technology and processes in daily life.
Democratic	Understanding nature of science is important in informed decision-making on socio-scientific issues.
Cultural	Knowing about nature of science is a need to appreciate the science as a product of contemporary human culture
Moral	Understanding nature of science helps development of an understanding the norms of scientific community that includes moral commitments that are important for society.
Science Learning	Knowing about nature of science facilitates the learning of science subject matter

Note: The table was structured by considering Lederman (2007).

Parallel to the importance of NOS for biological literacy, ideas of graduate-level biology education students on the NOS aspects are the most determinative factors of their scientific literacy levels. Biologically literate graduate students might make informed decisions about teaching and learning on biology, evaluate claims and explanations of biology, manage scientific problems in daily life and use scientific knowledge to produce useful means. In spite of importance of NOS knowledge in graduate-level education, the limited number of educational studies showed existence of some misunderstandings of science teacher educators and graduate students even if they completed their graduate-level courses and theses or dissertations (Chang, 1995; Irez, 2006). Similar to science teacher educators and graduate students, prospective teachers were also showed to have misunderstandings about the NOS aspects (Blanco and Niaz, 1997). The similar misunderstandings of prospective teachers and teacher educators or graduate students are indicators of inefficiency of the graduate programs. To describe ideas of graduate-level students in biology education on the NOS aspects has an importance to consider graduate-level experiences for improvement of NOS understandings and might provide an evidence to consider structure of graduate programs on biology education.

Rationale of the Study

Biology lessons are taken from beginning of high school to graduate level under the title of biology. Biology courses provide fruitful contexts for teaching the aspects of NOS by providing examples of biology as scientific discipline. The discussion on the variation of NOS understandings as products of epistemological beliefs across scientific disciplines including biology is still waiting for consensus and support. Schwartz and Lederman (2008) found that the NOS views of scientists from different disciplines did not differentiate with scientific context. In contrast, Paulsen and Wells (1998) found that epistemological beliefs of college students were related to disciplinary context. Moreover, Jehng et al. (1993) found that graduate students had more sophisticated ideas on tentativeness of scientific knowledge than the lower grade students. As another interesting factor, Paulsen and Wells (1998) found that age was also contributor of difference in epistemological understandings. The authors stated that the more people are getting older, the more they will have sophisticated epistemological understandings. Similar to the findings of Paulsen and Wells, Marzooghi, Fouladchang and Shemshiri (2008) found the

change in age is an important factor to explain epistemological differences between younger and older university students. All of these studies indicated the effect of contextual and personal characteristics on differences in epistemological understandings and understandings about NOS aspects vary toward graduate level education. Specifically, it is assumed that variation increases due to more focused and narrower specialization experiences. The most important difference between graduate and undergraduate degrees is to get opportunities for studying freely on a more specific field of study. For example; students do not have enough opportunity to conduct their own scientific project until they reach to master or doctorate level. The students have been making their own scientific research projects by taking part in a graduate program. Graduate level courses and studies are thought as experiential contexts for sophisticated scientific knowledge construction. In the process of knowledge construction, individual experience in the context of a discipline is the most important factor to understand structure of knowledge, validation ways, tentativeness, importance of creativity and socio-cultural factors in science. In the literature of NOS, there is no enough study focusing on a specific discipline with the participants at the level of graduate education. In graduate level programs, students might develop more permanent and effective understandings about the NOS aspects, so there is a need to conduct studies to determine the current situation by taking disciplinary differences into account. Therefore, the purpose of this study is to investigate the understandings of the graduate students in a biology education department about the aspects of nature of science.

Method

In this study, qualitative methodology was used with the "questionnaire of definitions" and "VNOS-C" as data collection tools (Fraenkel and Wallen, 2003). VNOS-C was developed by Lederman et al. (2002) whereas "questionnaire of definitions" was developed by researchers. The VNOS-C questionnaire has 10 generic items. As such, studying on the effect of context on the NOS understandings for different scientific disciplines might be problematic when only VNOS-C is used. But, the word association technique has advantages to provide traces for understandings of the participants and using cognitive traces about the NOS aspects for specific science fields might provide clearer picture to determine discipline-dependent NOS understandings. So, "questionnaire of definitions" structured by using word association technique might be useful to provide disciplinary point of view for studying differences in the NOS understandings. In this study, both general understandings and discipline specific understandings of the graduate students on the NOS aspects were determined by using VNOS-C and "questionnaire of definitions" together. This way of measurement was thought as more comprehensive than only relying on use of VNOS-C or the discipline-specific questionnaire.

The questionnaire of definitions is an open-ended questionnaire including questions regarding to biology discipline (see Table 3). In the questionnaire, the participants should use the provided words for their answers to any question. This way was chosen to provide discipline-specifity of the answers. The words provided in the questionnaire were determined by finding common words used to define selected words from three high school textbooks. Determination of the words was conducted by word-association technique. As the other instrument of the study, VNOS-C is an open-ended questionnaire which has 10 generic items on science-related aspects. One item example about social and cultural values in science includes the following question (Lederman et al., 2002).

Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

a. ***If you believe that science reflects social and cultural values****, explain why and how. Defend your answer with examples.*

b. ***If you believe that science is universal****, explain why and how. Defend your answer with examples.*

This study was conducted with a case study approach. The group of participants is a case due to the members' specific characteristics, graduation from biology education department, studying on biology education as master fields, age of them, the stage of their educational level, their interest in research and willingness to participate in the study. The participants were determined with the purposive sampling and then their consent were taken to participate. The aim of the study and preventions for potential harms and for confidentiality were explained to them. In the data collection phase of the study, word association technique was used to construct "questionnaire of definitions" first and, then the questionnaire and VNOS-C were applied as the main data collection tools. Data were analyzed by using descriptive analysis (Yıldırım and Şimşek, 2006). For the data analysis, description frame of McComas (1998), Lederman et al. (2002) for NOS aspects was used as analysis criterion.

Participants

The study was conducted with four participants enrolled in a master program in biology education. All of the participants have received education from biology education department as an undergraduate program before their masters programs. The participants took the same type and number of the courses during the years of the undergraduate degree. Undergraduate biology education program was a five-year program. The participants of the study will be indicated with their pseudonyms including BE-1, BE-2, BE-3 and BE-4 to provide confidentiality.

BE-1 is a male at the age of 25. He is a research assistant in the department of biology education for two years. He graduated from 5 year program of biology education in 2005. He has also been studying environmental education in his master thesis for two years. He did not take any course or seminar on epistemology, history of science and philosophy of science. He mentioned that he reads books on the issues of popular science, world classics, history, and religion once a week. As the other participant, BE-2 is also a male at 25 years old. Similar to BE-1, he is a research assistant in the department of biology education. He graduated from 5 year program of biology education in 2005 and was accepted for master program in 2005. He did not come across issues of epistemology, history of science and philosophy of science as course issue or seminar topic before. BE-2 has been studying on the environmental education as a master study. He informed that he reads books on environmental education and biology once a month. As the third participant from biology education major, BE-3 is a female research assistant at the age of 27. She graduated from five-year program of biology education in 2005 and began master program of biology education department at the same year. She has been studying on her thesis about "cell biology lab environment" for two years. She did not take any course and seminar on the issues of epistemology, history of science and philosophy of science. She also stated that she gives time for reading book about history and social sciences everyday. Also, she said that she likes issues of philosophy of science and finds them interesting. The fourth participant- BE-4 is a female at the age of 25. She has a job which is related to demography of population in the capital city of Turkey. She graduated from five-year biology education program in 2005 and was accepted to master program of the same department. Her study topic is about "nano-scales in textbooks". She explained that she did not take any course and seminar on the issues of epistemology, history of science and philosophy of science. As stated by her, the word she used to explain her reading frequency is "always "and she reads on history. Main characteristics of the participants are presented in table 3.

Table 3.
Main Characteristics of The Participants

Participants	*BE1*	*BE2*	*BE3*	*BE4*
Age	25	25	27	25
Gender	Male	Male	Female	Female
Field of Study	Biology Education	Biology Education	Biology Education	Biology Education
Stage of Graduate Study	Course Taking	Course Taking	Course Taking	Course Taking
Taking Course on Epistemology, History, Philosophy of Science	No	No	No	No

Process

In the study, data gathering process had four main stages. These are "word association application", "construction of questionnaire of definitions", "application of questionnaire of definitions" and "VNOS-C application". The word association technique is one of the most useful tools for getting knowledge about words stored in short-term memory. For word association, 8 concepts about the aspects of nature of science were determined by investigating three high school biology textbooks in order to provide common points for all participants. High school level was selected for investigation due to the fact that it is the first time for the students to see biology with its name as a different school subject. A nationwide curriculum is used throughout the country; Turkey, therefore, content of textbooks is the same for all high schools. For that reason, selection of words about the aspects of nature of science from high school biology textbooks was found to be useful to conduct a word association study. The selected main words are "biology", "science", "scientist", "experiment", "laboratory", "hypothesis", "theory" and "law". These are the most appropriate concepts to study on the nature of science aspects. Schunk (2000) stated that short-term memory has a capacity which comprises seven to nine objects. For that reason during application, 12 min. was given to the participants to complete nine spaces for each of eight words.

After the determination of associated words with the main words coming from high school textbooks, questionnaire of definitions was constructed by determining common words in the answers of the participants in word-association application. In the questionnaire, the participants were asked to write down definitions of "biology", "science", "scientist", "experiment", "hypothesis", "theory" and "law" by using the common words in their definitions. But, the two important changes were made in this stage. First, "experiment" and "laboratory" titles were combined under the title of "experiment" due to similarities of retrieved words for them. Second, a new question was added to get more detailed knowledge about definitions of "hypothesis", "theory" and "law". So, there was no word for question 9, the participants were asked to use words for the question 8. At the same time, there was also no word for question 3, since this question was combination of two questions and required to use words of question 1 and 2. The questions of questionnaire of definitions, main words selected from the biology textbooks and the chosen words from word association stage for each definition can be seen in table 4.

Table 4.
Questions of Questionnaire of Definitions and Chosen Words from Word Association Stage for Each Definition

No	Questions	Chosen Common Words from Word-Association Application	Main Words Used in Word Association Application
1	How can you describe "biology" by using one or more of the given words?	Living, Plant, Animal, Birds, Insects, Amphibians, Microorganisms, Fungi, Nature, Fish	Biology
2	How can you describe "science" by using one or more of the given words?	Scientist, experiment, investigation, progress, invention, easier life, history, technology, discovery, study, laboratory, communication, nature, education, learning, observation, examining, biology, world, report, etics	Science
3	How can you describe "biology as a science" by using the definitions you gave for "biology" and "science" title?		-
4	How can you describe "experiment" by using one or more of the given words?	Control, laboratory, measurements, subject, result, investigation, reason, observation, data, comprehension, teaching, study, researcher, scientists, task, biology, time, equipment, hypothesis, guniea pig, microscop, comparison, report, artificial environment, science, development, invention, innovation, responsibility, patience, attention, guide, law, theory	Experiment and laboratory
5	Write down a number into the space corresponding to the given characteristics regarding to scientists by indicating the most important as 1 and the least important as 21. If you want to add different characteristics, please write down space below and give an importance number by considering all characteristics.	Intelligent, doubtful, researcher, observer, interrogator, adventurer, curious, investigator, hard-worker, agile, resolute, money-lover, open-minded, free, un-dogmatic, unsupportive, expert, objective, enterprising, disobedient, striver	Scientist

Table 4.

6	How can you describe "hypothesis" by using one or more of the given words? and give an example for "hypothesis".	Evidence, experiment, scientist, observation, result, reason, questions, investigation, reasoning, comment, certainty, time, science, causality, foresight, mistake, tentativeness, curiosity, problem, solution, benefit, scientific method, temporary solution, way, experimentation, content, nature, experiment with control	Hypothesis
7	How can you describe "theory" by using one or more of the given words? and give an example for "theory" and explain it.	Investigation, observation, evidence, discussion, being scientific, reasoning, biology, experiment, certainty, scientist, guinea pig, reason, invention, scientist, question, supposition, variable, uncertainty, nonsense, comment, evidence, nature, accuracy, consequence, tentative, acceptable, rule, benefit	Theory
8	How can you describe "law" by using one or more of the given words? and give an example for "law" and explain it.	Fixed, correct, constant, scientist, observation, concept, logical, possible, to be discovered, nature, science, certain, law, problem, experiment, evidence, end, universal, not to be repeated, conclusion, fact	Law
9	Is there any relationship between theory, hypothesis and law? explain it by giving examples.		-

The data gained from the questionnaire of definitions were analyzed by descriptive data analysis approach as a qualitative approach. Then, one participant from the group was chosen to apply VNOS-C to get more detailed information about the aspects of nature of science and to overcome time limitation indicated by the participants. In the selection of the participant, data gathered from the questionnaire of definitions, understandability of writings and writing ability were considered. The data gained from VNOS-C were analyzed by using the same method with the data of the questionnaire of definitions.

Results

Under this title, answers of the participants to the questionnaire of definitions and VNOS-C will be explained.

Graduate Students' Responses to the Questionnaire of Definitions

The participants' answers to the question of "How can you describe "biology" by using one or more of the given words?" showed that they generally focused on the investigation objects, aims of the discipline and used the key words of "science" and "branch of science" to describe biology.

For the definition of biology, the participant BE-1 stated that "*Biology is a science which investigates livings, their relationships with each other in the nature, their morphologic and physiologic structures, functions of the structures, and association of them (livings) in terms of being relative*". The other participant, BE-3 described the biology as "*the branch of science which investigates livings*". Similar to BE-3, BE-4 stated that "*biology is the branch of science which investigates livings. If the variation amount among livings is considered, microorganisms, plants, animals, fungi etc. are in the investigation field of biology*". The other male participant, BE-2 described biology in a similar way by emphasizing the term of nature. He stated that "*biology is a branch of science which investigates nature, living components of nature, plants, animals, microorganisms, birds and insects*".

While the participants used basic terms and short sentences to describe biology, they made their definitions for the question of "how can you describe "science" by using one or more of the given words?" more complicated. They used processes of science, some terms related to technology and nature in their definitions.

For the definition of science, the participant BE-1 described science as "*the process of explanation of natural phenomena by need or inquiry and with using previous knowledge (literature)*". In a different approach, BE-3 stated that science is "*knowledge which is obtained by observation, investigation, inquiry and experiments and is useful for comfortable life*". Similarly, BE-4 explained that "*it (science) evolves as results of scientists' observations, workings and investigations*". In addition, BE-4 emphasized usefulness for life and ethical issues as unrelated issues with the question. BE-4 explained these issues that "*Scientific improvements might provide easiness in life. Whether or not these issues are ethical is dependent on person*". The last participant, BE-2 described science by using the terms of processes, products of it and places to do science. He stated "*science is an occupation that provides comfort in life and technological development which are results of scientific inventions, discoveries made by scientists who are studying in lab and out of lab on phenomena of nature*".

For the other question; "How can you describe "biology as a science" by using the definitions you gave for "biology" and "science" title?", participant BE-1 gave an answer as " *biology is a basic science the aim of which is to get useful knowledge for humankind and which investigates livings and all effective factors on them*". BE- 3 gave the similar definition with the answer of the first question, she stated that "*it (biology) is the branch of science which investigates livings*". BE-4 described biology as a science by explaining that "*it (biology) is a science which observes and investigates livings*". When looked at the last participant; BE-2, it can be seen that nature emphasis is clear. He explained that "*biology as a science is an occupation which investigates nature, phenomena of nature, brings the phenomena into agenda of humankind and finds solutions to the problems of nature*".

The question of "How can you describe "experiment" by using one or more of the given words?" was answered by BE-1 as citing to the "process definition". He described the experiment as "*the process for data collection and measurement about focus concept by controlling all other factors during an investigation*". Differently, BE-3 stated that an experiment is "*a work that is done in laboratory by observation or other research techniques to control whether a problem is true or false*". For this definition, BE-4 explained that experiments are "*the works that are done in laboratory by researcher or scientists and requires time and patience*". In addition to this definition, BE-4 stated that "*scientists or researchers can develop their hypothesis to theory or construct a new hypothesis with the results (of the experiments). Then, if the experiment supports the hypothesis, it becomes theory and law*". BE-2 also used "works" definition for the experiment. He described that experiments were "*works that is related to scientific and unscientific problems and require patience, carefulness, comparison, sometimes include observations which can not be done in a short time, is carried out in lab environment with different tools, microscopes*".

The summary of the results on the definitions of the participants on biology, science, biology as a science and experiment show that the participants define science and biology as different things. In addition, they have also used the term "observation" as the only definition of science not for biology or biology as a science. At the same time, they have limited understanding on the definition of science in general.

As another issue, they were asked to order the important characteristics of scientists from the most important to the least ones in the questionnaire of definitions. The five most important and five least important characteristics are presented in the following table.

Table 5.
The Most and the Least Important Characteristics of Scientists for the participants

Participant	The most important characteristics	The least important characteristics
BE-1	Objective, Un-dogmatic, Not subjective, Investigative, Questioning	Adventurer, Quick, Free, Rebel, Money-focused
BE-2	Investigative, Intelligent, Skeptical, Adventurer, Hard-worker	Struggling, Searching, Money-lover, Rebel, Expert
BE-3	Curious, Broad minded, Questioning, Observer, Investigative	Quick, Expert, Adventurer, Rebel, Money-lover
BE-4	Un-dogmatic, Objective, Hard-worker, Resolute, Not subjective	Expert, Intelligent, Adventurer, Rebel and Money-lover

In table 5, it is seen that the participants have believed that scientists are *not subjective*, *objective* and *un-dogmatic*. It is an indication of belief on "objective science" and attribution of the characteristics which can not be attributed to common individuals to scientists.

The definition of hypothesis varied from one participant to another, BE-1 defined hypothesis as "*questions we asked ourselves for solutions of problems by using results of observations which were made after clarifying problems*". Then, he used the following sentence as an example; "*anopheles should be vector for malaria*" for a hypothesis. BE- 3 stated that a hypothesis is "*tentative solution one scientist recommended for a problem after his or her observation*". Her example for a hypothesis is that "*After respiration, livings produce carbon dioxide that has acidic characteristic*". Similarly, BE-4 described hypothesis as "*tentative solution for problem in scientific method*". Her example for a hypothesis was about health; "*people who smoke cigarette will be lung cancer*". BE-2 also defined hypothesis as a tentative solution, his definition is that it is "*tentative solution way a scientist constructed after his or her observations and investigations with cause-effect relationship on problem*". And his example is that "*gas that is come about after the respiration has acidic characteristic*".

The answers to the questions "How can you describe "theory" by using one or more of the given words?, and give an example to "theory" and explain it" were also varied. BE-1 stated important points by giving many examples. He explained that "*hypotheses that are corrected always by experiments with control will be accepted after a time and will become theory*". His examples for theory are "*starling hypothesis, key-lock model, and evolution theory*". In spite of lack of examples, BE-3 stated that theories are "*uncertain scientific results coming from evidences of many observations, experiments and investigations*". She gave "cell theory" as an example. BE-4 explained that it is "*a step of scientific method that is uncertain and more correct than hypothesis*". She also used "*cell theory*" as an example. As the last participant, BE-2 defined it as "*acceptable and uncertain assumptions scientists reached about a scientific problem after their experiments, investigations and observations*". His examples were "*evolution theory*" and "*cell theory*".

The definitions about "law" have many important characteristics to see epistemological position of the participants. BE-1 described "law" by using the following sentence; "*if theories give correct results every time without differences for time, place and person, they will become laws*". He stated "*gravitation law*" and "*laws of thermodynamic*" as examples. Then, BE-3 explained that laws are "*unchanging scientific facts which are gathered by evidences of many observation, experiments and investigations that support each other*". Her example is also "*gravitation law*". BE-4 emphasized comparison with theory and she explained that "*it (law) is universal and is more correct that theory. Laws are unchanging facts"*. She gave "*Mendel's laws*" and "*gravitation law*" as examples. BE-2 defined laws as "*scientific facts and ordinances accepted by everybody and constructed by experiments and observations on a scientific problem*". His example for law is "*Mendel's laws*".

Although they stated and defined hypothesis, theories and laws, they were asked to compare them in terms of relationships. BE-1 stated that "*the way for law passes by hypothesis and theory*". Then, he drew a flow chart as like the following figure;

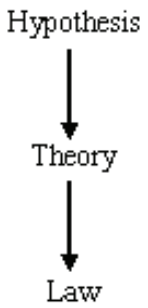

Figure 1. Relationship between Hypothesis, Theory and Law explained by the Participant BE-1

BE-3 described a way to explain the relationship among hypothesis, theory and law. She stated that "*hypotheses are suggested with evidences of the first observations. Then, the hypotheses are transformed to theories by supports of various experiments and investigations. If the data gathered from the experiments and investigations do not support hypothesis, it can be changed. If theory is supported by various investigations and is not disproved, law that is universal fact is constructed*".

BE-4 tried to explain the relationship by a figure and her sentences. She stated that "*hypotheses can be changed. Theory is true until it is disproved. Cell is known by everybody, but it is still a theory. Because, biochemical events in it (cell) did not emerge. Law is universal, gravitation law affects all matter and there is a certainty*". She also modeled her ideas with the following figure;

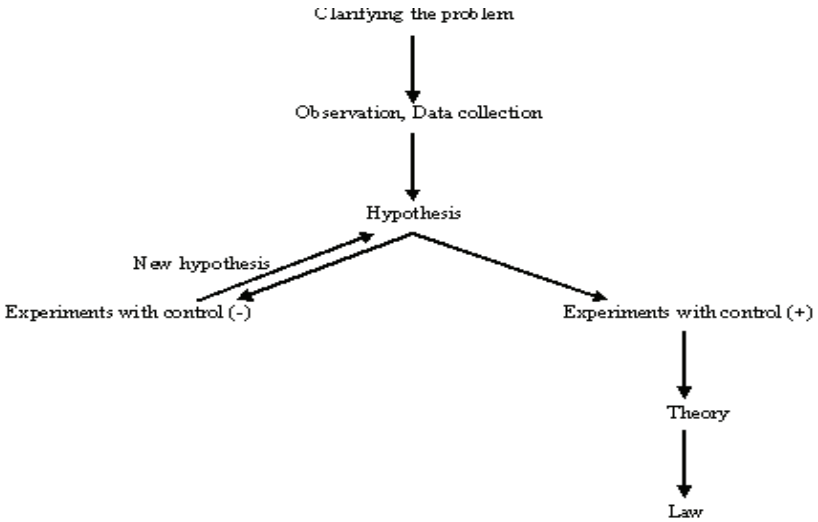

Figure 2. Explained Relationship between Hypothesis, Theory and Law by the Participant BE-4

BE-2 used an example to explain relationship he considered. He stated that "*there is a relationship among hypothesis, theory and law*" and he added that "*Hypothesis; livings emerged by changes of old anthropoid livings. Theory; this hypothesis becomes theory with various observations and investigations. Law; this theory left as a theory due to the fact that its universality and scientific validity were not discussed*".

In summary of the answers to the questions regarding to hypothesis, theory, law and their relationship, the participants have presented the belief that there is hierarchy between theory

and law; laws are more correct and accepted by everybody. At the same time, they have believed existence of a translation from theory to law by the support of more evidence and repetition. As such, the ultimate fate of all well-supported scientific knowledge is law and laws are not tentative while theories can be changed.

Graduate Student's Responses to VNOS-C

For the application of VNOS-C, BE-1 was selected due to his comprehensive data gathered from the questionnaire of definitions, understandability of his writings, writing ability and time limitation to apply VNOS-C to all participants.

BE-1 described science as "*rights that are not approved to be false at present and are systematically constructed with human being's curiosity and needs*". After his definition of science, he discriminated religion and philosophy from science by saying that "*although results of religious and philosophic issues include logical thinking, resource of religion is heavenly, close to criticism and unchangeable*". Then, he stated that "*philosophy do not conduct experiments and can not test any idea, it continuously alleges new ideas…. But, science can be tested and continuously gives same results. Philosophy and science is open for developments and regeneration. These have many problems, but they can be overcome whereas religion can not be changed*". In parallel to the answers on the definition of science in the questionnaire of definitions, the participants defined science as rights that are not falsified yet.

For the role of experiment in science, he stated that experiment is a "*technique that shows the testability characteristic of science. It is artificial environment to test scientific knowledge that exists in fact or claimed to be existence. In the formation of scientific knowledge, experiments with control are conducted in step of test of hypothesis*". After he stated the importance of experiments, he explained that "*modeling provides indirect ways (to test hypothesis)*". As another important issue, BE-1 wrote about theories and models. He stated that "*scientific theories change. We know that cell model changed and took many forms until it became the model accepted now. At the same time, atom theory was also explained by various models.…Theories change and develop. But, these occur systematically by construction with the new knowledge over the old ones as I stated in my science definition, people who will be able to develop, understand and teach new theories should know old theories*". Although he gave "*theory of evolution*" as an example for the theory, he did not accept to write about question including evolution and he stated that "*I believe that evolution is considered as a religion rather than scientific issue any more*". Then, he gave answer to another question about differences between theory and law that "*there is difference between theory and law. If theories give the same right results at every time and everywhere, they become laws. The law of gravity and laws of thermodynamics are examples of it. But, they are not unchangeable. Only, if any theory is approved to be inaccurate, it becomes less interesting and popular than a disproved law. If a law is changed, it opens a new era and is not easily accepted and also appearance of it in textbooks requires 50 years*". According to the answers provided in this paragraph, the participant believes in existence of hierarchy between theory and law, in addition, he also states that laws are not tentative.

For the atom model, he stated that "*scientists are certain that atom model is not simple as mentioned by previous scientists. Atom that is composed of quarks is just begun to be understood. With the light of knowledge, it changes and deve*lops". For the question about definition of species, he explained that "*scientists reached their knowledge about species by using observation and their old knowledge. But, there may be more definitions and different rights of different persons about the issue*".

For explanations about dinosaurs, BE-1 wrote that "*dinosaurs are un-testable results found by logical thinking with available evidences. One of these results may be correct or both of them may be correct*". In a similar vein, his answer to the question about society, culture and sciences showed that "*science reflects societal values. For this, we should look at social science rather than natural sciences. But, at the same time, science is universal, and this is generally seen in natural sciences*". And for the last question about imagination and science, BE-1 wrote that "*imagination may be used and not be used. For example, some inventions were found by chance whereas others were found by imagination. At the beginning, to find solutions for problem, imagination is used and after that time imagination should not be used*.

In summary of the believes of the participant on social and cultural effects in science and role of creativity and imagination in science, the participant claims that there is difference between social science and pure science in terms of social and cultural effects that affects social sciences rather than pure science. At the same time, the participant states that role of imagination in science is limited to planning phase of a research.

Discussion and Conclusion

For the first aspect, definition of science, the participants have misunderstandings including science as occupation and body of knowledge. In the literature of NOS, science is described as a way of knowing and it is based on observation and evidence (McComas, 1998, Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002). As another point on discipline-specific view, the participants' definition of science and biology presented a distinction between biology and biology as a science. While the participants defined biology as a "branch of science which investigates livings", they defined science as "the process of explanation", "knowledge" and "occupation". In this finding, there is one interesting point including definitional unrelatedness of biology and science. Although biology was used for providing more familiar context to think about the aspects of nature of science, the participants focused on subjects of biology and different type of livings in their definitions. The discipline dependency of the understandings of the participants for definition of science aspect has been shown by using two different approaches to collect data. The participants have been using observation or validation terms for defining "science" while they have been using very different concepts to define biology as a scientific discipline. This is an indication of discrepancy in understandings on general science and biology.

To determine understandings of the participants about "universally accepted one way to do science", their definitions of experiment were investigated, but any unit could not be found in the definitions of them. Then, the answers to VNOS-C were investigated and it was not also found any unit for this aspect. As another point, for the characteristics of scientists, understandings of participants showed important misunderstandings. The participants stated the characteristics such as "objective" and "un-dogmatic" in the part of the most important characteristics. Especially, objectivity aspect is more emphasized in the part of the most important characteristics by majority of the participants. But literature explains that scientist is not objective when he or she begins to study; he or she has a background (McComas, 1998, Lederman, Abd-El-Khalick, Bell, and Schwartz, 2002). Similar results were reported by Blanco and Niaz (1997) and Irez (2006).

As the other aspect, tentative nature of scientific knowledge was not understood enough by the participants. The participants, in their definitions of theory, law and hypothesis, stated that theory and hypothesis are changeable and temporary while they claimed that laws are unchangeable and fixed. In answers to VNOS-C, BE-1 also emphasized unchangeable nature of laws and changeability of theories. Then, he indicated a hierarchical relationship between hypothesis, theory and law by writing "*If theories give the same right results at every time and everywhere, they become laws.* Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) stated that every form of scientific knowledge is tentative. It can be said that discipline-dependent answers and VNOS-C answers are similar for the aspect of hierarchy between theory and law. This is an indication of common misunderstandings of the participants on hierarchy between theory and law. For this aspect, it does not matter whether you use generic or discipline dependent items.

For social and cultural embeddedness of scientific knowledge, BE-1 explained an important distinction between social science and pure science. He believed reflection of social values in science, but only for social sciences. He wrote that "*science reflects societal values. For this, we should look at social science rather than natural sciences. But, at the same time, science is universal, and this is generally seen in natural sciences*". But, McComas (1998) and Abd-El Khalick (2006) explained social and cultural embeddness of science. As found in this study, social and cultural embeddednes aspect is the clearest difference between the different disciplines. This aspect might effectively

be used in NOS studies. For example; other aspects of NOS can be studied by incorporating them into example social and cultural cases on different disciplines to check variability of the understandings of the graduate students.

For the creativeness and imagination in science, there was no answer to the questions of the questionnaire. In VNOS-C answers, BE-1 stated that imagination is a need for science and it can be used in planning, but use of imagination after the beginning phase should not be a case. The literature explains that creativeness and imagination are also important to produce scientific knowledge in all stages of scientific process (McComas, 1998, Lederman, Schwartz, Abd-El-Khalick and Bell 2001).

As the interesting point for disciplinary difference of understandings, the participants gave examples from biology for hypothesis and theory whereas law examples given included physics subjects. It is an indication of discipline dependency of the aspect, so there is need to study on where the difference lies. At the same time, this aspect should be thought with tentativeness aspect to draw more comprehensive conclusions.

Again, the participants falsely defined "experiment" and "science" as the same thing. It might be related to consider "existence of one way to do science" understanding. In this situation, science is falsely treated as the experimental method. The variation of understandings of graduate students on methods of different scientific disciplines are open issues to study further in graduate education context.

This study has been providing empirical evidence that the graduate students in this study have limited understandings on the aspects of NOS. At the same time, they have also understood biology and science as like different things. These results have importance for showing problems and initiation of change in mode of graduate experiences by focusing more epistemologically sound content. The other important point in this study is that majority of the participants are research assistants who will give the graduate courses after graduate years, so the results of this study might be effective to reflect on the aspects and can be used in graduate programs to show existent situation. As the other importance of this study, using two different approaches to collect data has been showing inefficiency of usage of only one generic instrument to determine NOS understandings.

Despite the strong sides of this study, there are also some limitations. As the first one, limited number of participants was included due to the qualitative nature of the study, so interpretation and generizability of the results requires careful investigation and decision. Again, the study is limited to investigate understandings about certain NOS aspects; therefore the study is limited to the number of the aspects investigated. The descriptive case study methodology was chosen for this study, the other more specific aspects should be studied by adding more comprehensive methods (eg. Phenomenography).

References

Abd-El-Khalick, F., Bell, R.L. & Lederman, N.G. (1998). The Nature of science and instructional practice: making unnatural natural. *Science Education*, *82*, 417–436.

Abd-El-Khalick, F. (2006). Over and over again: College students' views of nature of science. In L.B. Flick & N.G. Lederman (Ed.), *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning and Teacher Education* (pp. 389-425). Netherlands: Springer.

BSCS (1993). *Developing biological literacy*. Colorado Springs, CO: BSCS

Blanco, R. & Niaz, M. (1997). Epistemological beliefs of students and teachers about the nature of science: from "baconian inductive ascent" to the "irrelevance" of scientific laws. *Instructional Science*, *25*, 203–231.

Chang, T. (1995). An investigation of Taiwanese graduate students' beliefs about scientific

knowledge. *Bulletin of National Taiwan Normal University*, *40*, 583–618.

Demastes, S. & Wandersee J H. (1992), Biological literacy in a college biology classroom. *BioScience*, *42(1)*, 63–65.

Fraenkel, J.R. & Wallen, N. E. (2003). *How to design and evaluate research in education*. (6th ed.). McGraw-Hill, Inc.

Irez, S. (2006). Are we prepared?: An assessment of preservice science teacher educators's beliefs about nature of science. *Science Education*, *90*(6), 1113-1143.

Jehng, J. J., Johnson, S.D. & Anderson, R.C. (1993). Schooling and students' epistemological beliefs about learning, *Contemporary Educational Psychology, 18*, 23–35.

Klymkowsky, M.W., Garvin-Doxas, K & Zeilik, M (2003). Bioliteracy and teaching efficacy: what biologists can learn from physicists. *Cell Biology Education, 2*, 155–161.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of the nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1*, 135–160.

Lederman, N.G., Abd-El-Khalick, F., Bell, R.L. & Schwartz, R.S. (2002). Views of nature of science questionnaire: toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39(6),* 497–521.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research in science education.* Englewood cliffs, NJ: Erlbaum Publishers.

Marzooghi, R., Fouladchang, M. & Shemshiri,B. (2008). Gender and graduate level differences in epistemological beliefs of Iranian undergraduate students. *Journal of Applied Scences, 8 (24),* 4698-4701.

McComas, W. F. (1998). The Principle elements of the nature of science: Dispelling the myths. In W.F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 53–70). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Palmquist, B. & Finley, F. (1997). Preservice teachers' views of the nature of science during a postbaccalaureate science teaching program. *Journal of Research in Science Teaching, 34,* 595-615.

Paulsen, M. B. & Wells, C. T. (1998). Domain differences in the epistemological beliefs of college students. *Research in Higher Education, 39(4),* 365–384.

Schunk, D. H. (2000). *Learning theories: an educational perspective*. New Jersey: Prentice-Hall.

Schwartz, R. S., & Lederman, N. (2008). What scientists say: Scientists' views of nature of science and relation to science context. *International Journal of Science Education, 30(6),* 721-771.

Turkish Ministry of Education (2007). Turkish Ninth Grade Biology Curriculum. Ankara.

Uno, G. E & Bybee, R. W. (1994). Understanding the dimensions of biological literacy. *BioScience*, *44(8)*, 553-557.

Yıldırım, A., & Şimşek, H. (2006). *Sosyal bilimlerde nitel araştırma yöntemleri*. (5. Baskı). Ankara: Seçkin Yayıncılık.