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ORIGINAL ARTICLE

Investigating Understandings of Turkish Medical Graduate Students about Nature of Scientific Knowledge, Scientific Method, Characteristics of Scientists and Definition of Science

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Abstract

Background: Making informed decisions in medical research or applications are important for both daily life and professional life of medical researchers. Knowing about nature of science (NOS), as a part of biological literacy, is a component of informed decision making, since knowledge about nature of science is needed to be aware of pseudoscientific, dogmatic and inappropriate situations out of scientific approaches in medical research and applications. For example; making a decision about using an application to cure some diseases requires knowing about multidisciplinary nature of the problem and evaluating the nature of evidence on the application suggested by the literature. There are some studies focusing on NOS understandings of different groups of students, but there is a need to investigate NOS understandings of students by considering higher levels of education (graduate level) including medical graduate education and discipline specify of NOS aspects. **Objective*:*** This study purposes to investigate understandings of medical graduate students about the aspects of nature of science. **Method:** The study was a case study involving four participants studying on their MS research topics in medical sciences. The study was conducted by using questionnaire of definitions and VNOS-C as data collection tools. Data collection took two months, the interview was done after the analysis of answers to questionnaire of definitions. **Result:** According to the results, medical graduate students showed many misunderstandings about "universally accepted one way to do science", "objectivity", "tentativeness", "social and cultural embeddedness" of scientific knowledge", "creativeness and imagination in science" and "hierarchical relationship among hypothesis, theory and law and definitional differences of them". **Conclusion:** In conclusion, the participants do not have sufficient understandings to overcome problems on which making informed decisions is needed. In this manuscript, the results of the study will be described and limitations of the study and important points for further research will be explained.

Keywords
Nature of science, biology, medical education, graduate level

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Introduction

In today's changing world, biology became more important by studies conducted in the different areas of medicine including biomedicine and medical genetics. Reflection of many results and advances of these studies became apparent in lives of people. As a result of these popularity, importance and expansion, people are more dependent on getting knowledge of biology for their life and health. The aspect of biology for daily life might be named as biological literacy ability (BLA). The "BLA" might be described as an educational aim that includes having "working knowledge about biology and confidence about it, applying them into life situations, informed decision making by using biology knowledge, knowing nature of biology as "a way of knowing", understanding how scientists use methods and processes in biology works, engaging in discussion about biological phenomena, seeking valid information about biology [1,2,3]. Medical research and applications are subjects on which informed decision making should be applied by using biological literacy. In elementary and high schools where medical issues have been taught in biology courses, improving biological literacy is a beginning point to develop ability of making informed decisions in medical applications and research. In following years, medical education also involves biology courses. So biological literacy should be an important component of medical education. One of the most important aspects of biological literacy includes teaching about aspects of nature of science (NOS) as an objective for education of all people for biologically literate society [2, 3]. The NOS has many aspects for science education from scientific method to science in society (Nature of Scientific Knowledge, Scientific Method, Characteristics of Scientists and Definition of Science). As result of epistemological and educational studies, these aspects were determined to be necessary to teach about nature of science [4]. The aspects of nature of science are described as in the following sentences;

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

The studies on NOS understandings have been focusing on high school students and pre-service teachers [6-8]. Graduate level was not studied systematically, especially medical graduate students whom are expected to make informed decisions on their research and applications for improving people's health and life should be studied, since their decisions have important roles in other people's health and life. In both their professional life and daily lives, medical graduate students come across pseudoscientific, dogmatic and inappropriate situations that cannot be accepted as scientific explanations and moreover they should be prepared to make decision based on scientific rules in these situations by using their biological literacy skills and knowledge about NOS aspects. The importance of teaching NOS aspects for making informed decisions in medical context are also pointed out by Pettersen [9]. Therefore, this study purposes to investigate understandings of medical graduate students about the aspects of nature of science.

Importance of Biological Literacy and NOS for Graduate Medical Students

The medical education includes more science courses related to biology rather than physics and chemistry. The common biology courses taken by medical departments are microbiology, histology, physiology, genetics and pathology [9]. These courses are important context to learn about science and scientific processes out of other procedural medical courses and applications in medical settings. The studies with undergraduate and post-graduate levels showed some problematic situations about attitudes and understandings regarding to science in medical education. Although they took these courses, studies showed that medical students had positive attitudes toward pseudoscience including medical concern such as parapsychology, therapeutic touch, homeopathy and alternative medicine [9, 10]. In addition, Pena and Paco showed majority of medical students did not read or follow any sources related to science for a five-year long period and did not know definition and aspects of science [10]. Again, Pena, Paco and Peralta found that no physicians knew the pre-assumptions of science and majority of them did not know definition of scientific theory [11]. Graduate level studies about the aspects of the NOS in medical context were not found in the literature. But, apart from medical studies, Chang found that Taiwanese graduate students in the fields out of education hold firmly logical positivist epistemological position about scientific knowledge [12]. With these insufficiencies for making informed decisions on medical problems, importance of biology courses to learn NOS in medical settings becomes clearer as stated by Petersen [9]. One of the most important characteristics of scientifically literate individual, with narrower sense, biologically literate person is to distinguish and recognize NOS, scientific, unscientific, pseudoscientific, dogma and importance of evidence in the context of biology [10]. In their professional lives, medical graduate students will come across pseudoscientific, dogmatic and inappropriate situations out of scientific approaches and they should conclude about scientific ways in these situations by using their biological literacy skills and knowledge about NOS aspects. The need for and importance of teaching NOS aspects as a component of biological literacy in medical context are called by some researchers in medical field [9]. In this study, medical graduate students who had biology undergraduate degree were selected due to their similar and long-time undergraduate experiences with biology courses and to investigate NOS understandings by considering only one discipline (discipline specify of the understandings). Therefore, results of the study will make contribution for medical education literature and describe discipline specific NOS understandings of the medical graduate students.

Rationale of the Study

The discussion about the understandings on characteristics of scientific knowledge, science processes and science, across scientific domains is still waiting for consensus and support. Sources of these understandings might be related to previous experiences in daily life and activities with regard to various scientific disciplines. Paulsen and Wells found beliefs of college students on characteristics of scientific knowledge and knowing were related to disciplinary context whereas Schwartz and Lederman found the NOS views of scientists coming from different disciplines did not differentiate with scientific context [13, 14]. With this disagreement, Jehng, Johnson ve Anderson found that graduate students had more sophisticated ideas on tentativeness of scientific knowledge and Paulsen and Wells added that age was also contributor of difference in understandings on characteristics of scientific knowledge and

knowing [13,15]. They stated that the more people are getting older, the more they have sophisticated understandings on characteristics of scientific knowledge and knowing. Marzooghi, Fouladchang and Shemshiri also found the change in age as an important factor to explain understanding differences on characteristics of scientific knowledge and knowing between younger and older university students [16]. All of the studies that indicated the effect of contextual, personal experiences on differences in understandings on characteristics of scientific knowledge and knowing were provocative for this study. As explained by Paulsen and Wells, and Jehng, Johnson ve Anderson; understandings about NOS aspects vary toward graduate level education [13, 15]. Especially, 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 and to experience with real decision making situations in research process. For example; students do not have enough opportunity to conduct their own scientific project until they reach to master or doctorate level. In fact, approximation to or experiencing the scientific study conducted by scientists may be come about by taking part in a graduate study and courses or feeling ownership on a field of graduate level study. By considering this idea, graduate level courses and studies were thought as experience contexts for scientific knowledge construction. The process of knowledge construction is the time for development of aspects of NOS and individual experience is the most important factor in it. By the personal experiences taken in medical research processes, NOS understandings might also be shaped. Based on these understandings, decisions on nature of evidence, characteristics of scientific knowledge, quality of method and evaluation of nature of medical sciences are made. Therefore, there is a need to determine understandings of medical graduate students on NOS aspects. In the literature of NOS, there is no study with the participants at graduate level in medical education. In graduate level programs of medical education, students might develop more permanent and effective understandings about NOS aspects, so there is a need to inform medical instructors and lecturers about NOS understandings of the graduate students. With this rationale, the purpose of this study is to investigate the understandings of the medical graduate students about the aspects of nature of science.

Method

from biology department, studying on medicine as master fields, age of them, the stage of their educational level, their interest in research and willingness of them to participate. The participants were selected with the purposive sampling and then they were asked to participate in and the aim of the study and preventions for potential confidentiality were explained to them. The data collection process involving the “questionnaire of definitions” and “VNOS-C” as data collection tools took two months, since the interview was done after the analysis of answers to questionnaire of definitions. [17]. VNOS-C questionnaire is selected because its open-ended nature is more appropriate to collect data for description purpose of the study and to collect more naturalistic data than forced-choice instruments. VNOS-C was developed and validated by Lederman, Abd-El-Khalick, Bell and Schwartz whereas “questionnaire of definitions” was developed by researchers [5]. The VNOS-C questionnaire has many generic items on which the participants can give different answers regarding to anyone in 10 aspects of the NOS, so the effect of context on differences in the NOS understandings across scientific disciplines might be problematic

when only VNOS-C is used. The word association technique was used for preparing the questions of "questionnaire of definitions". The word association has advantages to provide context for definitions of the participants and to use cognitive traces about the issue. This way of data collection has also advantages to overcome the problem related to generic nature of VNOS-C. Data coming from the questionnaires were analyzed by using descriptive analysis [18]. For the data analysis, description frame of McComas, Lederman, Abd-El-Khalick, Bell and Schwartz for NOS aspects was used as analysis criteria[4,5].

Participants

The study was conducted with four participants enrolled in a master program on medicine. All of the participants received an education from biology as an undergraduate program before the master programs. The participants took the same courses during the years of the undergraduate degree.

Undergraduate biology program was a four-year program. Before the study, consent of the all participants was taken by asking them about willingness to participate in the study. The participants were informed about purposes, potential harms and benefits of the study. The participants of the study are indicated with their pseudonyms. As the first participant, PS–1 was a female at the age of 23. She had many relatives with related to research; her father, uncle and cousin were conducting research in the fields of environmental engineering, geography and food technologies. She graduated from four-year program of biology department and begun the master program of histology and embryology in 2007. She took the courses for her master degree during this study. She took a course on epistemology, philosophy and history of science but she did not participate in any seminar, panel or the other activities about them. She did not have any job. She informed that she reads a book on science or its content once a month.

The other participant, PS-2 was also a female at the age of 23. She graduated from biology department in 2006 and the department included four-year education. She focused on medical biology and genetics and her thesis was about cyto-genetic and mutations. She took the courses for completing the requirements of the department. She did not take any course on and participate in any seminar, conference about epistemology, philosophy and history of science. She stated that she reads frequently books on scientific issues. She did not have any relative who was related to research activities. The other female participant, PS-3 was 27 years old. She did not have any relative who was related to research activities. She graduated from four-year program of biology department in 2004 and was accepted to the master program in 2005. She completed minimal course requirement of the department of histology and embryology. She was studying on the application part of her thesis during the study. She did not have any job and wants to be scientist in her field of study. She did not take any course on epistemology, philosophy and history of science before. She explained that she did not participate in any seminar, conference or other related activities about epistemology, philosophy and history of science. She also stated that she is not selective on reading and reads on any issue twice a week. The last participant, PS-4 was a female at the age of 25. She graduated from four-year biology department in 2005. She was accepted to the master program in 2007. She did not have any relative who was researcher on any scientific issue. She took the courses for her degree requirement during the study. Her field of study was about biochemistry and hematology. She did not take any course on and participate in activities about epistemology, philosophy and history

of science before. Her reading frequency was once a week and reading issues aware about articles on her field.

Process

In the study, data gathering process had four important points. These were "word association application", "construction of common 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 of concepts about aspects of nature of science were determined by investigating three high school biology textbooks in order to provide common points for all participants in biology. High school level was thought for investigation due to the fact that it was the first time for the students to see biology with its name as a different school subject. Again, one curriculum was used by all areas of the country; Turkey, therefore, content of textbooks and subject order were the same for all high schools. So, words about the aspects of nature of science in high school biology textbooks were found to be useful to conduct a word association study. The concepts were "biology", "science", "scientist", "experiment", "laboratory", "hypothesis", "theory" and "law". For the application, 12 min. was given to the participants to complete nine spaces for each word. Schunk stated that short-term memory has a capacity which comprises the number of objects from seven to nine [19]. By considering the capacity of short-term memory and developmental level of participants, nine spaces were found to be appropriate.

After the determination of associated words about the main words coming from high school textbooks, questionnaire of definitions was constructed by determining common words for the participants. In this questionnaire, the participants were asked to write down definitions of "biology", "science", "scientist", "experiment", "hypothesis", "theory" and "law" by using the given words as a context which was gathered from the common words for the group in word association papers. But, the two important changes were made in this stage. The first one was to combine "experiment" and "laboratory" titles under the title of "experiment" due to similarities of retrieved words for them.

The second was to add a new question to get more detailed knowledge about definitions of "hypothesis", "theory" and "law". This question and the questions of questionnaire of definitions and the chosen common words from word association stage for each definition except for "biology as a science" can be seen in the table 1. Because the words of definitions for biology and science were used to answer the question on "biology as a science".

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 for interview to get more detailed information about the aspects of nature of science. In the selection of the participants for interview, data gathered from the questionnaire of definitions, understandability of their writings and writing ability were considered. Interview was conducted in form of written response to adapted VNOS-C. The data gained from VNOS-C were analyzed by using the same method with the data of the questionnaire of definitions.

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Table 1. Table of questions of questionnaire of definitions and chosen common words from word association stage for each definition

No	Questions	Words
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
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
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
5	Write down a number into the space corresponding to the given characteristics 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, hardworker, agile, resolute, money-lover, open-minded, free, undogmatic, unsupportive, expert, objective, enterprising, disobedient, striver
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
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
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
9	Is there any relationship between theory, hypothesis and law? explain it by giving examples.	

Result

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

Answers of Medical Graduate Students to the Questionnaire of Definitions

The first of the participants, PS-1 described biology as "*branch of science which investigates nature and livings, microorganisms, insects, birds, animals and plants*". Similarly, PS-4 also defined biology as "*branch of science which studies on plants, animals, microorganisms and all livings in the world*". PS-2 added a new living group (fungi) to the definitions and described biology as "*branch of science which investigates microorganisms, fungi, birds and plants*". The last definition of biology was PS-3's definition; her definition was "*branch of science which investigates livings*".

After the definitions of biology, the participants were asked about their definitions of science. PS-1 explained that science covers "*studies which were based on observation, experiment and investigation, and were conducted for more comfortable life, improvement and learning in communication with the world by new inventions*". PS-4 mentioned that science is "*works of scientists who conducted studies for providing more comfortable life by using experiments in laboratory*". Similarly, PS-3 defined science as "*studies of scientists which were conducted for learning and providing comfortable life, in laboratories in most of time and were based on observation, investigation, and experiment*". As the last, the definition of PS-2 was that "*observations and investigations of scientists to provide technological development and comfortable life and their actions for inventions by experiments and research construct science*".

The answers of the participants to the question of "How can you describe "biology as a science" by using the definitions you gave for "biology" and "science" title?" also varied with focus terms used by the participants. PS-1 emphasized the term "*branch of science" and defined biology as "a branch of science which investigates nature and livings and tries to prove correctness of research in itself by observations and discoveries*". Again, PS-4 also focused the term of "*branch of science"* and she defined it as *"branch of science which is ageless and alive*". PS-2 did not give any response to this question. PS-3 used the term of "*making experiments*" and she defined biology as "*making experiments for understanding nature and livings*".

The participants defined "experiment" with various adjectives and processes. PS-1 stated that an experiment is "*the study conducted by scientist to prove his or her hypothesis he or she constructed by using time, materials, observation and investigation, this study requires responsibility, patience and carefulness*". PS-2 also explained that experiments are "*studies that require knowledge, patience, carefulness, responsibility and these studies are conducted with certain knowledge and measurements to develop a theory by scientists*". As another participant, PS-4 defined experiments as "*studies of biology or science that require carefulness, knowledge, patience, responsibility and cause to new inventions*". PS-3 stated that experiment is "*to study on subjects and to get data to test hypothesis in laboratory environment*".

As the other question, they were asked to order the important characteristics of scientists from the most important to the least ones. The five most important and five least important characteristics can be seen in the following table 2.

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Table 2. The most and the least important characteristics of scientists

Participant	*The most important characteristics*	*The least important characteristics*
PS-1	Investigative, Struggling, Un-dogmatic, Researcher, Observer	Quick, Adventurer, Objective, Free, Money-lover
PS-2	Intelligent, Investigative, Skeptical, Researcher, Hard-worker	Un-dogmatic, Quick, Adventurer, Rebel, Money-lover
PS-3	Money-lover, Rebel, Entrepreneurial, Expert, Investigative	Free, Hard-worker, Questioning, Resolute, Objective
PS-4	Investigative, Hard-worker, Skeptical, Questioning, Curious	Struggling, Free, Adventurer, Observer, Money-lover

The definitions of hypothesis were given with the examples by the participants. Variation in definitions was also worth to consider. PS-1 defined it as "*an idea claimed by scientists and that is not certain and can be tested by research, logic, forethought and experiment*". Her example was that "*Do plants make photosynthesis?*". In a different way, PS-4 described hypothesis by indicating "*results of observations*". Her definition was that a hypothesis is "*result of observations in which scientific methods are used and solutions for problems are found*". The examples given by her were that "*determination of freezing point of water*" and "*water freezes in zero degree of Celsius*". PS-2 defined hypothesis as "*transformation of an unknown event to questions with curiosity by scientists*." Interestingly, example of PS-2 was similar to the example of PS-1 in spite of certain difference in their hypothesis definitions. The example of PS-2 was that "*Do plants make photosynthesis?*". Differently from the others, PS-3 defined it as "*tested forethoughts which are not proven and are claimed with logic about reasons and possible solutions of a problem*". Her example was "*matter transfer in cell membrane is carried out by help of pores*".

As similar to the definitions for hypothesis, definitions for theory varied very much. PS-1 explained with theory of evolution as an example that theories are "*comments or rules that can be uncertain, changeable and absolute, and are constructed by experiments of scientists*". PS-4 defined that theory is "*a knowledge that develops when hypotheses are tested and certainness is constructed by experiments*" and she did not give any example. PS-2 stated that theories are "*changeable and discussable assumptions that are not certain and found by observations*". She also gave "*theory of evolution*" as an example. The last, PS-3 defined it with the example of "*theory of evolution*" as "*discussable and logical results which are not universal and the evidences of them are found with the experiments and investigations driven by hypothesis of scientist*". She also gave "*theory of evolution*" as an example.

For the law definitions, the key term used by participants was "*fact*". PS-1 defined law as "*scientific fact which is approved to be true and logical by all scientists and continuously supported by observations and experiments*". Her examples were "*laws of Newton*" and "*Action-reaction law*". As a different definition, PS-4 stated that laws are "*results*

that are true, unchangeable and like universal acts and are gained when theories are absolute correct". Her example was *"Water boils in 100 degrees of centigrade*". PS-2 defined it as "*unchangeable and fixed facts which cannot be found again and are proven by experiments of scientists*". Her example was "*laws of Newton*", more specifically "*law of gravity*". PS-3 described a law as "*fixed and unchangeable scientific facts which are accepted as universally true by help of repetition of experiments with control on theories in different times and by different scientists*". Her example was also the same with the others; she used "*law of gravity*" as an example. For the relationship among law, theory and hypothesis, the participants gave nearly similar answers. PS-1 stated that "*if hypotheses are proven to be true, they will be theory and if theories are accepted by all scientists in the world, they become laws*". She also added that "*the theory of evolution remained as theory due to the fact that it is still not accepted by all of scientists in world*". PS-4 emphasized the process among them. She stated that "*hypothesis, theory and law work together. Firstly, hypothesis is set and then tested by experiments with control. They become theories. Soon, the theories become laws and certain*". In a different way, PS-2 preferred to use a figure as like the following;

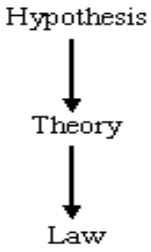

Figure 1. Relationship model among hypothesis, law and theory explained by PS-2

The last participant; PS-3 explained that "*theories are constructed by testing and concluding of defined hypotheses via experiments with control. Theories are not universal facts and can change. Laws are formed when the theories are proven to be true and certain and become universally true. Laws are unchangeable*".

Answers to VNOS-C

In interview data, the PS-4 defined science shortly as "investigation". She then explained that "*there is no only one true in science and it includes questioning, rights are found and corrected or disproved whereas religion includes believing God and has only one right*". She did not write anything about philosophy. Then, she defined again experiment as "*application to test validity of hypotheses*" and she added that "*experiments are required to investigation, conducting research and showing examples. Their correctness was easily accepted by different of groups of people*". For the question about change in theories, she explained that *"theories change. Proof of a theory can be provided and accepted as true for that time, but, then the solution can be seen as inefficient. For example; we understood that the smallest part (of matter) is atom. But, we divided it into small particles*". For differences between theory and law, she stated that "*there is difference between theory and law.*

Theory is proven in a time interval, but, if it becomes a law, it is not changed. For example, everybody knows that if glucose rate of a sick with diabetes increases to 80-100, this person is sick. This is a law". The participant proposed a way to study on an atom, she stated that scientists "*study on atom by dividing it*", and so, they can gather evidence for atom models. For the difference in viewpoints, the participant stated that "*science is variation, people look at life from different windows due to their differences in viewpoints, imaginations, and perceptions on power of proof*". She wrote about science, culture and societal values that "*science is universal; it does not consider religion, language, race. Everywhere, insulin cure is started to decrease glucose level in satiety. Therefore, this hormone is found in pancreas in everybody and it is secreted by β cells*". For the question about imagination and science, she stated that "*science requires imagination. Imagination is used in planning, process and concluding part of experiments*".

Discussion

Their definition of science included science as "studies based on observation, experiments and investigation", "works of scientists", "studies of scientists for learning", "observations and investigations of scientists" and "investigation". In the literature of NOS, science is described as a way of knowing in which evidence and observation are two important components [4, 5]. In spite of naïve understandings about "dependence of scientific knowledge on evidence and observation" aspect, it was partially explained by one participant from medical graduate students. She stated that "science is based on observation, investigation and experiment". Although biology was used for providing more familiar context to think about aspects of nature of science, the participants focused on issues of biology and different type of livings in their definitions. They used the words of "science", "branch of science", "a basic science", "occupation" and "making experiments" as for the definition of biology. With these perspectives, it can be said that all of them are naïve in terms of definition of science and, evidence and observation dependent nature of science. McComas and, Lederman, Abd-El-Khalick, Bell and Schwartz defined science from NOS perspective as "a way of knowing" and they stated that "scientific knowledge is based on evidence and observation" [4, 5]. On this finding it can said that discriminating scientific knowledge from pseudoscientific and dogma requires knowing about evidence and observation based nature of science. This aspect should be discussed explicitly in instructions on medical problems.

To describe 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 seen that PS-4 saw an experiment as only one way to do science. She stated that "*experiments are required to investigation, conducting research, and showing examples".* Again, PS-4 and PS-3 in their explanations of relationship among hypothesis, theory and law stated that hypotheses are tested by experiments. According to McComas and, Lederman, Abd-El-Khalick, Bell and Schwartz, there is no universally accepted one way to do science [4,5,20]. For the process of experiments, the participants interestingly, emphasized individual factors included in an experiment as "patience", "responsibility", "carefulness" and "knowledge" rather than scientific processes. It is an open issue to research.

For the characteristics of scientists, understandings of participants showed important misunderstandings. But, medical graduates gave also some knowledgeable understandings by ordering positive and

negative characteristics such as "money-lover", "observer" and "skeptical" in the part of the most important characteristics and positivistic words such as "un-dogmatic" and "objective" in the part of the least important characteristics. Especially, objectivity aspect is more emphasized in the part of the most important characteristics by some medical graduates. Studies on nature of science show that scientist is not objective when he or she begins to study; he or she has a background [4,5,8]. Only PS-4 stated that scientists look at life from different windows due to their differences in viewpoints, imaginations and perceptions.

As another aspect, tentative nature of scientific knowledge was not understood enough by the participants. Medical graduates, 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. PS-4 emphasized unchangeable nature of laws and changeability of theories. In answers to VNOS-C, PS-4 emphasized unchangeable nature of laws and changeability of theories.

For social and cultural embeddedness of scientific knowledge, any unit did not emerge in questionnaire of definitions. But, answers to VNOS-C provided some important results.PS-4 stated that science is universal and there is no place for language, race and religion differences in it and she added that insulin care is applied to decrease glucose level in satiety everywhere. PS-4 showed pure positivistic understanding about this aspect. According to McComas and, Lederman, Abd-El-Khalick, Bell, and Schwartz, scientific knowledge is embedded in social and cultural context, and tentative [4, 5, 7]. This aspect is very important because medical problems are not embedded in an unchanged disciplinary context, majority of the problems in medicine are complex and needed to be treated with the questioning approach on nature of the knowledge regarding to solutions.

For the creativeness and imagination in science, PS-4 stated that imagination is a need for science and it can be used in planning, during process and concluding part of experiments. The literature explains that creativeness and imagination are also important to produce scientific knowledge in every stage of scientific process [4, 5, 20]. It is very important to use creativity in every stage of medical research, since there is a need to increase effectiveness of research by thinking about the most usable choice in overcoming problems. This aspect should be considered in instructions on medical problems.

The participants used "idea", transformation" process, "tested forethoughts" and "results of observation" to define hypothesis. This variation is worth to investigate, because they received education from the same department and saw the same courses and practices. With this definitional variation the participants showed the same understandings about hierarchy among hypothesis, theory and law. Medical graduates stated that laws are more certain, accepted, true and universal. In parallel, they suggested one-way hierarchy in which hypothesis becomes theory with the support of evidence; theory becomes law with acceptance of others. Accordingly, laws are at higher place in hierarchy, then theories come and the lowest place is for hypothesis in the hierarchy. But, as stated by McComas and, Lederman, Abd-El-Khalick, Bell, and Schwartz, there is no hierarchy among hypothesis, theory and law [4,5]. They are different knowledge forms. Hypotheses are tentative proposals which are based on observations and evidence. Theories are constructed explanations about phenomena whereas laws are explanations about relationships about phenomena [20]. This finding has a separate place in this study, because discriminating the types of scientific

knowledge is the beginning point for deciding on nature of scientific knowledge and nature of scientific method. In addition to understandings on law and theories, scientific models frequently used in medical research should also be investigated to describe understandings of medical graduate students. As the interesting point, they gave examples from biology for hypothesis and theory whereas law examples given included physics subjects. Again, the participants falsely defined "experiment" and "science" as the same thing. They are open issues to study further in medical context.

Based on the results of this study, it can be said that this study has limited number of participants, so interpretation and generalisability of the results requires careful investigation and decision. It is important that the main purpose of this study was to describe understandings of a case on NOS aspects. In the study, limited number of NOS aspects are considered, the other more specific aspects (e.g. nature of communication among medical researchers) should be studied with more comprehensive methods.

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