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Professional Development of Elementary and Science Teachers in a Summer Science Camp: Changing Nature of Science Conceptions

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Abstract: Many countries all over the world have recently integrated nature of science (NOS) concepts into their science education standards. Providing professional support to teachers about NOS concepts is crucially important for successful implementation of the standards. For this purpose, a summer science camp was offered to elementary and science teachers. The main objective of this research study was to investigate the progress in specific NOS concepts made by the participant teachers. The responses of the teachers regarding the NOS concepts were obtained through VNOS-C questionnaire and scored using a rubric developed by McDonald (2008). The scored teacher responses were analyzed conducting MANOVA and Repeated Measures MANOVA statistical tests. It was observed that 'naïve' or 'limited' views of NOS were predominant in the pretest results of the participant teachers. At the end of the summer science camp, some of the participant teachers' conceptions experienced a transition to more 'informed' views of NOS. The amount of the progress made by the teachers appeared to be free from their specific teaching disciplines.

Introduction

Contemporary science education standards all over the world have recently been emphasizing the importance of supporting students to become scientifically literate individuals (Abd-El-Khalick, Bell, & Lederman, 1998; Hodson, 1998; Khishfe & Lederman, 2006; Laugksch & Spargo, 1996; Lederman, Antink, & Bartos, 2014). Developing an adequate level of understanding of the nature of science (NOS) concepts is one of the prerequisites required for scientific literacy (Abd-El-Khalick, 2005; Afonso & Gilbert, 2010; Allchin, 2014; Herman & Clough, 2014; Hogan, 2000; Lawson, 2010; Kim, Yi, & Cho, 2014; Leung, Wong, & Yung, 2015; McComas, Clough, & Almazroa, 2002; McDonald, 2010; Posnanski, 2010; Schwartz, Lederman, & Crawford, 2004; Van Dijk, 2014; Wong & Hodson, 2008). People equipped well with the contemporary interpretations of NOS concepts are usually more prone to make better informed decisions regarding personal and societal issues (Khishfe, 2012). Creating better prepared minds to overcome current problems related to science and technology is fulfilled only through providing a satisfactory education to students about NOS concepts. Becoming conscious consumers of scientific information, making better judgments about socioscientific issues, and taking better roles in decision making processes are just a few among many benefits of a proper comprehension of NOS concepts (Driver et al., 1996). Furthermore, learning more content in science is intrinsically reinforced by developing an adequate understanding of NOS concepts

(Akerson, Nargund-Joshi, Weiland, Pongsanon, & Avsar, 2014; Lombrozo, Thanukos, & Weisberg, 2008).

Despite the vital position of NOS in becoming a scientifically literate individual, the ultimate characteristics of science are still an unresolved issue in the philosophy of science (Abd-El-Khalick, 2006; Lederman, 2006; Smith & Scharmann, 1999). Specifically, the distinguishing characteristics of science from non-science (known as the demarcation problem) have long been the subject of dispute among the prominent philosophers of science [e.g. Feyerabend (1975); Kuhn (1962); Lakatos (1976); Laudan (1977); Popper (1959)]. While logical positivist scientists who portray science as a systematic and objective source of knowledge position themselves on the one end of the controversy, some of the radical philosophers like Fayerabend who does not give any special attributes to science expressed with the motto “anything goes” stay on the other end of the controversy. It is usually possible to locate the other opinions about the true characteristics of science to somewhere between these two opposite sides. There is an ongoing struggle between traditional and postmodern interpretations of science so called “science wars” (Brown, 2001; Pigliucci, 2010; Rose, 1997; Tauber, 2009). This suggests that the true characteristics of science are not yet a settled construct among the philosophers of science. However, all those fine discussions made in the discipline of philosophy are not very meaningful in the K-12 education setting (Lederman, 2007; Lederman, Antink, & Bartos, 2014). That is because, in portraying science accurately in school context, little, if any, disagreements exist about the specific aspects of NOS appropriate for the cognitive development of the students (Abd-El-Khalick, Bell, & Lederman, 1998). The objective of presenting an accurate picture of science to students in science classes has made NOS one of the most essential constructs of science education. A closer look at the education literature also reveals that NOS has recently become one of the most popular research topics in science education.

Although no consensus regarding a specific definition of NOS exists among historians, philosophers, scientists and science educators (Abd-El-Khalick, 2006; Hodson & Wong, 2014; Lederman, 2006; Smith & Scharmann, 1999), this construct in education context provides “a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors” (McComas, Clough, & Almazroa, 2002, p.4). The following are the most prominent aspects of NOS suitable for the cognitive development of K-12 students and relevant to their daily lives: tentative nature of the scientific knowledge, theory-laden character of the scientific knowledge, empirical base of the scientific knowledge, socially and culturally embeddedness of the scientific knowledge, imagination and creativity involved in the scientific knowledge, myth of the scientific method, and distinction between scientific theories and laws (Abd-El-Khalick, 2012; Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, 2006; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Like scientific knowledge itself, none of the negotiated aspects of NOS is free from modifications or changes over time (Lederman, 2007; Lederman, Antink, & Bartos, 2014). This means that NOS as one of the most fundamental constructs of science education is always dependent on renewed perceptions of science and, as such, subject to change.

Science has been one of the key figures in historical development of humanity and deserves a fair representation in society. However, various media sources continually promote a distorted image of science. Even textbooks are criticized for maintaining the circulation of common misconceptions about science among students (Bauer, 1994; Blachowicz, 2009; Clough, 2006; DiGiuseppe, 2014). Students’ erroneous perceptions of science are partly caused from “textbooks…written to provide students with the popular, contemporary, cleaned-up, and prejustified accounts of the behavior of the natural world" (Monk & Osborne, 1997, p.405). Considering the unprecedented growth of internet sources within the last decade, the internet is hosting a continually increasing number of the websites rich in content with all sorts of fake information, bizarre ideas, unsupported claims and hoaxes. Young minds unaware of the essential values of science are more vulnerable to the negative effects of these technological artifacts. A strong society immune to the ill effects of mythical, paranormal, pseudoscientific, supernatural and superstitious beliefs arises from introducing students to a more realistic image of science. The major responsibility in educating students with an adequate understanding of the specific aspects of NOS is intensively dependent on the efforts of their teachers. However, only a limited number of teachers at schools are knowledgeable enough about NOS concepts and competent sufficiently to engage their students with relevant experiences targeting the specific aspects of NOS (Abd-El-Khalick & Akerson, 2004; Guerra-Ramos, Ryder, & Leach, 2010; Lederman, Wade, & Bell, 2002; Posnanski, 2010; Wong & Hodson, 2008). Some of the research studies in the literature reached similar conclusions for Turkish schools (e.g. Dogan & Abd-El-Khalick, 2008; Koksal & Cakiroglu, 2010). Despite the heavy emphasis given to NOS in science education standards, little progress has been made in preparing teachers having the capabilities of supporting their students to gain a comprehensive understanding of NOS concepts (Hanuscin, Lee, & Akerson, 2010).

Although teachers' failure to possess an adequate level of understanding in NOS concepts might be attributed to several factors, none is more influential than the unsatisfactory NOS education given to them in their undergraduate education (Backhus & Thompson, 2006; Herman, Clough, & Olson, 2013; McComas, Clough, & Almazroa, 2002). Embedding NOS concepts in science method courses, research projects or science content courses is the most common approach worldwide in providing NOS education to preservice teachers (Backhus & Thompson, 2006; Cofre et al., 2014; McComas, Clough, & Almazroa, 2002). However, separate courses completely dedicated to NOS concepts are usually missing from preservice teacher education programs (Aflalo, 2014; Backhus & Thompson, 2006; Cofre et al., 2014). In a survey research study conducted with science teacher educators at 113 different teacher education institutions in the USA, Backhus and Thompson (2006) reported that "the majority of institutions (more than two-thirds) do not have a nature of science course of any variety" (p.74). According to the study, only 6 % of high school teacher preparation programs and 5 % of middle school teacher preparation programs required teacher candidates to take a separate NOS course. As of 2006, the figures in the study illustrate that the overwhelming majority of the teacher candidates graduated from their programs without even taking a single NOS course. Since 2006, it seems that not much change has been observed in the US teacher preparation programs because "no published studies in the last 8 years report an increase in the number of programs that require preservice science teachers to complete a course focusing on the NOS and NOS pedagogy" (Herman & Clough, 2014, p.2). Despite the intensive promotion of teaching NOS concepts to students in recent science education reform documents all over the world, "very little is done formally toward ensuring a presence of the nature of science with preservice science teacher preparation programs" (Backhus & Thompson, 2006, p.77). In fact, the major focus of many science and elementary teacher preparation programs is predominantly centred on teaching the relevant content knowledge in science (Aflalo, 2014). There is usually a little, if any, mention of the production and acceptance process of the scientific knowledge. Therefore, many of the beginning teachers step into the profession without having even a basic understanding of NOS concepts.

Becoming a good teacher is a lifelong effort. Teacher preparation programs constitute only the first step of the journey in becoming an effective teacher. Professional development programs come to the forefront in helping in-service teachers enhance their capabilities in teaching profession. Due to the fact that teacher education programs offer little, if any, to teacher candidates about NOS as an instructional outcome (Aflalo, 2014; Backhus & Thompson, 2006), professional development programs offered to the practicing teachers have the potential to compensate their shortcomings. However, the busy schedule of the practicing teachers in a school year usually keeps them from participating in professional development programs. As such, informal education settings such as summer science camps might be an ideal learning environment for students and teachers to compensate their lack of knowledge in NOS (Fields, 2009; Foster & Shiel-Rolle, 2011; Leblebicioglu, Metin, Yardimci, & Berkyurek, 2011; Spector, Burkett, & Leard, 2012). Informal education covers a broad range of learning environments outside the school context including, but not limited to, natural history parks, geological sites, zoos, botanical gardens, and science museums (Hofstein & Rosenfeld, 1996). The informal education given in these learning environments usually takes place voluntarily and is unstructured, open-ended, learner-directed, and non-curriculum based (Hofstein & Rosenfeld, 1996). Learners in informal education settings engage with the authentic learning environments representing the soul of practicing scientific culture (Adams, Gupta, & DeFelice, 2012).

Supporting in-service teachers to enhance their views of science is but only the first step to be taken in promoting the integration of NOS in science classes as an instructional outcome. It is the first step because having a sophisticated understanding of NOS by teachers does not automatically lead to satisfactory results in their teaching practices of NOS (Akerson, Pongsanon, Weiland, & Nargund-Joshi, 2014; Bartos & Lederman, 2014; Bell, Matkins, & Gansneder, 2011; Lederman, 2006; Lederman, Antink, & Bartos, 2014; McComas, Clough, & Almazroa, 2002; Schwartz & Lederman, 2002). In order for teachers to create an effective learning environment for their students, they need to possess not only a sound knowledge of NOS concepts but also an adequate level of pedagogical content knowledge for NOS (Schwartz & Lederman, 2002; Van Dijk, 2014). Therefore, practicing teachers should be supported via professional development programs carefully designed for them to enhance their understanding and teaching performances of NOS (Lederman, Antink, & Bartos, 2014).

Providing a quality education to students about NOS concepts requires effective teaching strategies. In the literature, the approaches adopted by science educators in teaching the specific aspects of NOS to learners are usually displayed in three general forms; namely implicit, explicit and historic approach (Abd-El-Khalick & Lederman, 2000; Aflalo, 2014; Akerson, Abd-El-Khalick, & Lederman, 2000; Gess-Newsome, 2002; Khishfe & Abd-El-Khalick, 2002; Rudge & Howe, 2009). Chief among them is the explicit approach when it comes to effectiveness of the NOS instruction given to learners (Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Matkins, & Gansneder, 2011; Khishfe, 2013; Khishfe & Abd-El-Khalick, 2002; Khishfe & Lederman, 2007; Peters, 2012; Schwartz & Lederman, 2002). That is primarily because NOS concepts in an explicit approach are treated as a cognitive learning outcome and taught to students in a similar way to teaching any other cognitive learning outcome in science content knowledge (Aflalo, 2014; Lederman, Lederman, Antink, 2013; Schwartz & Lederman, 2002). On the other hand, the implicit teaching approach considers NOS concepts as a part of affective domain and assumes that affective learning goals are achieved naturally as a by-product of engaging students in scientific inquiry activities and authentic research experiences without drawing their attention directly to any specific aspects of NOS (Abd-El-Khalick & Lederman, 2000; Bell, Matkins, &

Gansneder, 2011; Khishfe & Lederman, 2007). Unlike the implicit approach, learning outputs in explicit approach are carefully “planned for instead of being anticipated as a side effect or secondary product” (Akindehin, 1988, p.73) and addressed directly in the instructional process (Abd-El-Khalick & Akerson, 2009; Khishfe & Lederman, 2007; Schwartz & Lederman, 2002). With respect to the context of an explicit approach, instruction of NOS concepts is either integrated or non-integrated into specific science content (Bell, Matkins, & Gansneder, 2011; Eastwood et al., 2012; Khishfe & Lederman, 2007). Explicit instruction is usually accompanied by a reflection component through which learners are given sufficient opportunities to discuss and question specifically addressed aspects of NOS (Aflalo, 2014; Schwartz & Lederman, 2002). The historic approach of teaching NOS concepts involves presenting the relevant anecdotes from the history of science to introduce learners to the targeted aspects of NOS (Abd-El-Khalick & Lederman, 2000; Bell, Matkins, & Gansneder, 2011). Although the aforementioned approaches of NOS instruction are all used by science educators to some degree, the education literature asserts that learners should be confronted explicitly with the targeted aspects of NOS and allowed to reflect on the instructed aspects of NOS.

Research Process

In response to the several criticisms directed to the inadequate education of teachers about the NOS concepts in the education literature, an attempt was made to support teachers to enhance their comprehension of the certain aspects of NOS through a week-long summer science camp. This camp was offered to elementary and science teachers and a total of fifty teachers, twenty of whom were elementary teachers and thirty of whom were science teachers, attended the summer science camp sponsored by the Scientific and Technological Research Council of Turkey. The camp program aimed to provide professional support to practicing teachers in astronomy and NOS concepts. The main purpose of this research study was to investigate the effect of relatively shorter in-service professional development programs, a week-long summer science camp in this case, on teachers’ understanding of NOS concepts. The education given to teachers in the camp covered a broad range of instructional approaches ranging from implicit to explicit. However, in light of the several comments expressed in the literature regarding the ineffectiveness of implicit instruction of NOS concepts (Bell, Matkins, & Gansneder, 2011; Gess-Newsome, 2002), any of the implicit experiences engaged in by the participant teachers during the camp was reinforced with an explicit reflective instructional approach. This included interactive presentations about NOS concepts, group discussions about the specific aspects of NOS, talks about the historical development of astronomical knowledge, and communicating with scientists about producing scientific knowledge in astronomy. During the camp program, participant teachers also had ample opportunities to observe the practicing astronomers in the Astronomy Observatory Center. These opportunies allowed teachers to be a part of an authentic learning environment, which offered a first-hand experience to them in the production of scientific knowledge. Activities developed specifically for the participant teachers in the camp program started in the early hours of the day (around 9:00 am) and lasted till the late hours of the night (around 11:00 pm) in each day. Among all applicant teachers, only those with less than five years of teaching experience were selected to attend the summer science camp. The mean teaching experience of participant teachers were 2.5 years. The following research questions guided this research study:

1. What were the NOS conceptions of teachers at the beginning of a summer science camp?
2. Was there any difference between the initial NOS conceptions of elementary teachers and science teachers at the beginning of a summer science camp?
3. What were the effects of participating in a summer science camp on the NOS conceptions of teachers?
4. Was there any difference between the amount of progress in NOS conceptions made by elementary teachers and science teachers as a result of attending a summer science camp?

The summer science camp was offered to teachers in two consecutive sessions, each of which lasted for a week. In each session, ten elementary teachers and fifteen science teachers participated in a rich program covering a variety of activities related to both astronomy topics and NOS concepts. Data were collected from a total of fifty participant teachers, twenty of whom were elementary teachers and thirty of whom were science teachers. An adapted Turkish version of a scale, VNOS-C developed by Lederman, Abd-El-Khalick et al. (2002) was delivered to participant teachers at the beginning (pretest) and at the end (posttest) of the summer science camp. The primary motive behind using the pretest-posttest design was to inspect the learning gains of the participant teachers from the summer science camp regarding certain aspects of NOS. In the past forty years, researchers have developed several instruments for the purpose of uncovering the NOS conceptions of learners (Lederman, Wade, & Bell, 2002). These standardized instruments designed in a format with forced-choice items (e.g. Likert-type and multiple choice) were criticized for imposing the views of the researchers on the respondents rather than capturing a personal account of their true perspectives (Lederman, Wade, & Bell, 2002). Open-ended questions in the VNOS-C questionnaire, which draw no boundaries to respondents in expressing their views freely, distinguish it from standardized forced-choice instruments, which restrict respondents to choose one of the predetermined options (Lederman, Abd-El-Khalick et al., 2002). For more than a decade, the use of the VNOS-C questionnaire by many scholars with a variety of different participant groups, including high school students, college students, teacher candidates, and practicing teachers, has elevated its reputation among researchers with respect to its validity and reliability (Lederman, Abd-El-Khalick et al., 2002). Before completing the instrument in the study, the participant teachers were instructed that there were no right or wrong answers to be given to the questions in the VNOS-C questionnaire. This increased the likelihood that they provided their most sincere thoughts about the specific aspects of the NOS. The VNOS-C questionnaire used in this study was translated to Turkish language by the author and reviewed carefully by two science educators for accuracy and appropriateness of the translation. The VNOS-C questionnaire consists of ten open-ended questions targeted at eliciting the following aspects of the NOS: 1) Empirical and Tentative NOS; 2) General Structure and Aim of Experiments; 3) Validity of Observationally-based Theories and Disciplines; 4) Nature and Function of Scientific; 5) Differences and Relationship between Theories and Laws Theories; 6) Inference and Theoretical Entities; 7) Indirect Evidences and Scientific Theories; 8) Subjective or Theory-laden NOS; 9) Social and Cultural Embeddedness of Science; and 10) Creative and Imaginative NOS.

Data Analysis

In this study, a content analysis approach was utilized in analysing the responses given by teachers to the open-ended questions in the VNOS-C questionnaire. Content analysis "is a research technique for making replicable and valid inferences from text (or other meaningful matter) to the context of their use" (Krippendorff, 2004, p.18). The scoring of the responses was performed using a rubric adapted by McDonald (2008) from Abd-El-Khalick (1998). The scoring rubric consisted of a total of four categories, namely naïve, limited, partially informed and informed. Each specific category in the rubric was defined separately for each one of the ten questions in the VNOS-C questionnaire. Whereas a 'naïve' category corresponds to the least comprehensive view of NOS, an 'informed' category represents the most comprehensive view of NOS. In order to give a sense of the definitions used in the rubric, each one of these four categories is defined specifically for Question-5 (Differences and Relationship between Theories and Laws) in appendix A. Based on the rubric translated to Turkish language by the author, each response was coded independently by the author and another science educator. A score of 1, 2, 3, or 4 was assigned respectively to a 'naïve', a 'limited', a 'partially informed' and an 'informed' view. A response decided to be "irrelevant" was given 0 points. After the completion of the scoring process, the level of the agreement between the scores given by two individual scorers was calculated using Cohen's Kappa Coefficient. The value of Kappa Coefficient indicated a moderate agreement (0.73) between the overall scores assigned by the two independent scorers. Unequal scores assigned by the two scorers to the same teacher response were discussed together to reach a negotiated decision. The discussion process ended with complete agreement between the two scorers.

The difference between the pretest mean scores of the elementary teachers and the science teachers was examined using the MANOVA statistical test. This analysis aimed to find out if any significant difference exists between the NOS conceptions of the elementary teachers and the science teachers before starting the camp program. A Repeated Measures MANOVA statistical test was performed in analysing the difference between the pretest and posttest mean scores of the participant teachers. This analysis was made to figure out if attending the summer science camp program had any significant effect on the NOS conceptions of the attendant teachers. In addition, the analysis was undertaken to determine if the teaching disciplines of the teachers made any significant difference on their amount of progress from the camp program. Each specific aspect of the NOS was treated as a dependent variable in the MANOVA statistical test.

Study Results

Initial NOS conceptions of the teachers before attending the summer science camp were ascertained by the first research question. Any significant differences between initial NOS conceptions of the science teachers and the elementary teachers were investigated in the second research question. Based on the answers given by participant teachers to the open-ended questions in VNOS-C questionnaire, Table 1 displays the pretest mean scores of the science teachers and the elementary teachers. The overall pretest mean scores of the participant teachers in each specific aspect of NOS are given in Table 2. An answer to the first and second research question is provided using the figures in Table 1 and Table 2.

	Aspects of NOS	Teaching Discipline	Pretest Mean	Pretest SD	Univariate Test Statistics	Partial Eta Squared (η_p^2)
1	Empirical and Tentative NOS	S	1.73	0.64	F(1, 48)=.676, p=.415	0.014
		E	1.90	0.79		
2	General Structure and Aim of Experiments*	S	2.33	0.76	F(1, 48)=10.104, p=.003	0.174
		E	1.70	0.57		
3	Validity of Observationally-based Theories and Disciplines	S	1.27	0.69	F(1, 48)=.426, p=.517	0.009
		E	1.15	0.49		
4	Nature and Function of Scientific Theories*	S	2.20	1.00	F(1, 48)=16.650, p=.001	0.258
		E	1.05	0.94		
5	Differences and Relationship between Theories and Laws	S	1.30	0.60	F(1, 48)=3.200, p=.080	0.063
		E	1.05	0.22		
6	Inference and Theoretical Entities	S	2.20	0.61	F(1, 48)=2.286, p=.137	0.045
		E	1.95	0.51		
7	Indirect Evidences and Scientific Theories*	S	1.47	0.68	F(1, 48)=13.714, p=.001	0.222
		E	0.80	0.52		
8	Subjective or Theory-laden NOS	S	2.50	0.90	F(1, 48)=1.806, p=.185	0.036
		E	2.20	0.52		
9	Social and Cultural Embeddedness of Science	S	1.63	0.81	F(1, 48)=.916, p=.343	0.019
		E	1.85	0.75		
10	Creative and Imaginative NOS	S	1.43	0.73	F(1, 48)=.023, p=.881	0.001
		E	1.40	0.82		

*****significant at $\alpha=0.01$
S=Science Teacher, E= Elementary Teacher

Table 1 Univariate Test Statistics on the Pretest Results of Science and Elementary Teachers

Table 1 above yields the existence of a statistically significant ($p<0.01$) difference between the pretest mean scores of the science teachers and the elementary teachers in favour of the science teachers in the following three aspects of NOS: “General Structure and Aim of Experiments [F(1, 48)=10.104, p=.003, $\eta_p^2=0.174$]”, “Nature and Function of Scientific Theories [F(1, 48)=16.650, p=.001, $\eta_p^2=0.258$]” and “Indirect Evidences and Scientific Theories [F(1, 48)=13.714, p=.001, $\eta_p^2=0.222$]”. The large effect sizes ($\eta_p^2=0.174$, 0.258 and 0.222 respectively) imply the practical importance of the statistically significant differences in these three aspects of NOS. This result indicates that science teachers started the camp program with relatively higher scores than the elementary teachers in these specific three aspects of NOS. However, the results of the elementary and science teachers were either predominantly ‘naïve’ or ‘limited’. Other than these three aspects of NOS identified above, no statistically significant difference was found between the pretest mean scores of the science teachers and the elementary teachers in the remaining seven aspects of NOS. The figures in Table 2 below illustrate that the pretest mean scores of the participant teachers in majority of the aspects of the NOS have a general tendency to accumulate on ‘naïve’ or ‘limited’ views. This implies the inadequate understanding of the teachers in certain NOS concepts at the beginning of the summer science camp. Table 2 also indicates that the lowest pretest mean scores were obtained by teachers in the following three aspects of NOS: “Differences and Relationship between Theories and Laws (M=1.20)”, “Indirect Evidences and Scientific Theories (M=1.20)” and “Validity of Observationally-based Theories and Disciplines (M=1.22)”. MANOVA statistical test used to examine the difference between the pretest mean scores of science teachers and elementary teachers produced a statistically significant result [F (10, 39)=4.529, p=0.001; Wilks’ Lambda=0.463; η_p^2=0.537] suggesting that NOS conceptions of science teachers and elementary teachers exhibited some differences at the beginning of the summer science camp program.

The third research question in the study aims to examine the effect of the summer science camp on initial NOS conceptions of the teachers. Table 2 below denotes the pretest and posttest overall mean scores of the participant teachers in each specific aspect of NOS.

	Aspects of NOS	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Univariate Test Statistics	Partial Eta Squared (η_p^2)
1	Empirical and Tentative NOS	1.80	0.70	1.82	0.83	F(1, 48)=0.059, p=0.809	.001
2	General Structure and Aim of Experiments	2.08	0.75	2.10	0.68	F(1, 48)=0.362, p=0.550	.007
3	Validity of Observationally-based Theories and Disciplines*	1.22	0.62	1.56	0.78	F(1, 48)=4.871, p=0.032	.092
4	Nature and Function of Scientific Theories*	1.74	1.12	2.06	1.13	F(1, 48)=4.182, p=0.046	.080
5	Differences and Relationship between Theories and Laws**	1.20	0.49	1.80	1.17	F(1, 48)=12.857, p=0.001	.211
6	Inference and Theoretical Entities	2.10	0.58	2.10	0.68	F(1, 48)=0.046, p=0.831	.001
7	Indirect Evidences and Scientific Theories	1.20	0.70	1.32	0.77	F(1, 48)=1.874, p=0.177	.038
8	Subjective or Theory-laden NOS*	2.38	0.78	2.72	1.01	F(1, 48)=6.053, p=0.018	.112
9	Social and Cultural Embeddedness of Science*	1.72	0.78	2.08	0.83	F(1, 48)=5.954, p=0.018	.110
10	Creative and Imaginative NOS**	1.42	0.76	1.96	0.86	F(1, 48)=18.893, p=0.001	.282

*significant at α=0.05
**significant at α=0.01

Table 2 Univariate Test Statistics on Overall Teacher Progress

The difference between the pretest and posttest mean scores of the teachers analysed by Repeated Measures MANOVA statistics indicates an overall statistically significant result [F(10,39)=4.304, p=0.001; Wilks’ Lambda=0.475; η_p^2=0.525] suggesting that the summer science camp had a positive effect on NOS conceptions of the participant teachers. As displayed in Table 2 above, the overall mean scores of the teachers from pretest to posttest show a statistically significant improvement in the following six aspects of NOS: “Validity of Observationally-based Theories and Disciplines [F(1, 48)=4.871, p=0.032, η_p^2=0.092]”, “Nature and Function of Scientific Theories [F(1, 48)=4.182, p=0.046, η_p^2=0.080]", "Differences and Relationship between Theories and Laws [F(1, 48)=12.857, p=0.001, η_p^2=0.211]", "Subjective or Theory-laden NOS [F(1, 48)=6.053, p=0.018, η_p^2=0.112]", "Social and Cultural Embeddedness of Science [F(1, 48)=5.954, p=0.018, η_p^2=0.110]", and "Creative and Imaginative NOS [F(1, 48)=18.893, p=0.001, η_p^2=0.282]". The statistically significant figures displayed in Table 2 points out the positive influence of the summer science camp program on six of the NOS conceptions for the participating teachers.

The fourth research question in the study inquires into the difference between the progress made by the science teachers and the elementary teachers. Table 3 below displays the univariate test statistics of the difference between the pretest and the posttest mean scores of the science teachers and the elementary teachers.

	Aspects of NOS	Teaching Discipline	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Univariate Test Statistics
1	Empirical and Tentative NOS	S	1.73	0.64	1.97	0.67	F(1, 48)=3.761, p=.058
		E	1.90	0.79	1.60	0.99	
2	General Structure and Aim of Experiments*	S	2.33	0.76	2.10	0.80	F(1, 48)=5.231, p=.027
		E	1.70	0.57	2.10	0.45	
3	Validity of Observationally-based Theories and Disciplines	S	1.27	0.69	1.60	0.77	F(1, 48)=.003, p=.957
		E	1.15	0.49	1.50	0.83	
4	Nature and Function of Scientific Theories	S	2.20	1.00	2.43	1.07	F(1, 48)=.420, p=.520
		E	1.05	0.94	1.50	1.00	
5	Differences and Relationship between Theories and Laws	S	1.30	0.60	2.00	1.31	F(1, 48)=.608, p=.440
		E	1.05	0.22	1.50	0.89	
6	Inference and Theoretical Entities	S	2.20	0.61	2.10	0.80	F(1, 48)=1.152, p=.288
		E	1.95	0.51	2.10	0.45	
7	Indirect Evidences and Scientific Theories*	S	1.47	0.68	1.37	0.76	F(1, 48)=4.628, p=.037
		E	0.80	0.52	1.25	0.79	
8	Subjective or Theory-laden NOS	S	2.50	0.90	2.60	1.04	F(1, 48)=3.405, p=.071
		E	2.20	0.52	2.90	0.97	
9	Social and Cultural Embeddedness of Science	S	1.63	0.81	2.03	0.81	F(1, 48)=.122, p=.729
		E	1.85	0.75	2.15	0.88	
10	Creative and Imaginative NOS	S	1.43	0.73	1.90	0.84	F(1, 48)=.509, p=.479
		E	1.40	0.82	2.05	0.89	

*significant at α=0.05

S=Science Teacher, E=Elementary Teacher

Table 3 Univariate Test Statistics on Teacher Progress Based on Teaching Disciplines

According to Table 3, the overall difference between the progress made by the science teachers and the elementary teachers from pretest to posttest yields a statistically insignificant result [F(10,39)=1.764, p=0.101; Wilks' Lambda=0.689] suggesting that the overall gain of the participant teachers from the camp program is independent from their specific teaching disciplines. Only in two aspects of NOS ("General Structure and Aim of Experiments" and

"Indirect Evidences and Scientific Theories"), did the elementary teachers made significantly ($p<0.05$) more progress than the science teachers. Actually, the mean scores of the science teachers in these two specific aspects of NOS exhibited slight decline from pretest to posttest.

The statistical analyses made in this study have based on the scores assigned to the responses given by teachers to the open-ended questions in VNOS-C questionnaire. Providing some examples from the actual teacher responses is important in introducing the readers to the scoring process via displaying some of the representative views of the teachers scored as 'naïve, limited, partially informed or informed'. Furthermore, exemplifying some of the responses given by the teachers provides a better sense of their actual thoughts about NOS concepts. Some examples of the teacher responses in each specific aspect of NOS were presented in appendix B.

Conclusions and Implications

The pretest results of the teachers participated in this study indicated that the majority of them had not developed a profound insight into the various aspects of NOS. In other words, the number of 'naïve' and 'limited' views of the NOS concepts was dominant in the responses of the teachers at the beginning of the summer science camp. The teachers' highest pretest mean scores ($M=2.38$) were in "Subjective or Theory-laden NOS" aspect of NOS and their lowest pretest mean scores ($M=1.20$) were in "Differences and Relationship between Theories and Laws" and "Indirect Evidences and Scientific Theories" aspects of NOS. Of concern is that, even the highest pretest mean score of the teachers ($M=2.38$) corresponds only to a mediocre result and is far from satisfactory. This result is consistent with an ample number of research studies reporting teachers' inadequate understanding of NOS concepts (Abd-El-Khalick & Akerson, 2009; Bell & Lederman, 2003; Guerra-Ramos, Ryder, & Leach, 2010; Herman, Clough, & Olson, 2015; Southerland, Gess-Newsome, & Johnston, 2003). Inadequate conceptions of NOS held by the participant teachers in this study suggested that many of them started the camp program with a lack of prior reflection on NOS concepts. The chances were that only a few of the teachers had been introduced to the specific aspects of NOS in their undergraduate education as only science teachers are offered a separate NOS course in their third year of Turkish preservice teacher preparation programs. No course related to NOS is present in undergraduate elementary education programs. Needless to say that the elementary teacher preparation programs in the country graduate many students each year with an inadequate understanding of NOS concepts. The pretest results of the teachers in this study support this assertion.

It seems that introducing teacher candidates to NOS in their undergraduate education only through a single method course or a separate NOS course is usually far from preparing them to comprehend the specific aspects of NOS and to engage their students in appropriate experiences regarding NOS concepts (Aflalo, 2014; Herman, Clough, & Olson, 2013). Prospective teachers need extensive experiences in their undergraduate education in order for them to develop a higher level of understanding about NOS concepts. In addition, some science educators offering the specific NOS courses do not have an appropriate education about teaching NOS concepts. To further confound the problem, the lack of quality textbooks written on the subject limits the capabilities of science educators to help their students gain a better understanding of NOS concepts. Once graduated from a teacher education program, teachers experience a lot of difficulty in finding any formal education programs designed specifically to support their inadequate understanding of NOS concepts. In that respect, informal learning environments (e.g.

summer science camps as described in this study) emerge as a feasible option for practicing teachers to compensate their shortcomings in their comprehension of NOS concepts. Creating a scientifically literate generation as the overarching objective of contemporary science education standards is ultimately contingent upon the growing number of competent teachers, who maintain their education via attending the relevant professional development activities.

According to the pretest results, at the beginning of the summer science camp, science teachers were more informed about specific aspects of NOS than their elementary teacher colleagues. Specifically, science teachers were more informed about the: General Structure and Aim of Experiments, Nature and Function of Scientific Theories, and Indirect Evidences and Scientific Theories. This is not surprising given the inclusion of a NOS course in their preservice training. In addition, in contrast to elementary teachers, science teachers naturally have more interactions with the science content in which a myriad of the scientific theories is presented together with the specific evidences supporting them. The higher exposure of science teachers to the laboratory experiences in undergraduate science education program usually makes them more cognizant about scientific experiments. These experiences of science teachers might be presented as a contributing factor to their more informed conceptions in aforementioned aspects of NOS although no consensus in general exists among various research studies in the literature in regard to the influence of having more science content background on teachers' NOS conceptions (Morrison, Raab, & Ingram, 2009). Some of the research studies report the more traditional conceptions of science teachers than elementary teachers in certain aspects of NOS (Karaman & Apaydin, 2014; Morrison, Raab, & Ingram, 2009; Pomeroy, 1993). Similarly, there are research studies indicating more informed views of non-science majors in select aspects of NOS than science majors (Liu & Tsai, 2008; Miller, Montplaisir, Offerdahl, Cheng, & Ketterling, 2010). Some studies found no difference between NOS conceptions of researchers working in natural and social sciences (Bayir, Cakici, & Ertas, 2014). The contradictory conclusions about NOS conceptions of science majors and non-science majors in the literature might be considered as a sign of the unsatisfactory NOS education given in schools.

In comparison to the pretest mean scores of the participant teachers, their posttest mean scores exhibited a statistically significant improvement in the following select aspects of NOS: Validity of Observationally-based Theories and Disciplines, Nature and Function of Scientific Theories, Differences and Relationship between Theories and Laws, Subjective or Theory-laden NOS, Social and Cultural Embeddedness of Science, and Creative and Imaginative NOS. The improved mean scores of the participant teachers in select aspects of NOS from pretest to posttest might be interpreted as the positive influence of the summer science camp organized for the practicing teachers. Furthermore, the amount of teachers' progress in NOS concepts appeared to be independent from their specific teaching disciplines. This suggested that the camp program served all participant teachers equally regardless of their teaching disciplines. The vast majority of the research studies in the literature investigated the effectiveness of summer science camps organized for students. These summer science camps were offered to students with several different purposes including, but not limited to, increasing students' interest and attitudes toward science (Sheridan, Szczepankiewicz, Mekelburg, & Schwabel, 2011; Vekli, 2013), attracting students to STEM careers (Bhattacharyya, Mead, & Nathaniel, 2011; Bischoff, Castendyk, Gallagher, Schaumloffel, & Labroo, 2008; Crombie, Walsh, & Trinneer, 2003), enhancing students' science content knowledge (Davis, 2014; Fields, 2009; Williams, Ma, Prejean, Ford, & Lai, 2007), supporting students for scientific literacy (Foster & Shiel-Rolle, 2011), and improving students' NOS conceptions (Antink-Meyer, Bartos, Lederman, & Lederman, 2014;

Hirca, 2014; Liu & Lederman, 2002; Metin & Leblebicioglu, 2011). The aforementioned research studies reported the success of the short-term summer science camps to some extent in improving students' NOS conceptions. However, as demonstrated by these studies, the majority of summer science camps are organised for students rather than preservice and inservice teachers. When it comes to the research studies inquiring in the effectiveness of the summer science camps for preservice and inservice teachers, there are only a few in the literature (e.g. Logerwell, 2009; Naizer, Bell, West, & Chambers, 2003; Wallace & Brooks, 2014). Furthermore, it is quite unlikely to find any research studies focused primarily on the development of teachers' NOS conceptions in a summer science camp. In that respect, this research study filled a considerable gap in the education literature in terms of the effect of short-term summer science camps on teachers' NOS conceptions. The significant progress made by the participant teachers in some aspects of NOS might be attributed, in general, to the use of the explicit-reflective approach in the summer science camp program to support the NOS conceptions of the teachers. The effectiveness of the explicit-reflective approach in teaching the NOS concepts was expressed numerous times in the literature by many scholars (e.g. Bell, Matkins, & Gansneder, 2011; Khishfe, 2013; Scharmann, Smith, James, & Jensen, 2005). Any implicit experiences of the teachers in the camp program were reinforced appropriately through explicit references given to the relevant aspects of NOS. Despite participant teachers' relatively short exposure (a week in this case) to the camp program, several of them completed the camp program successfully with an elevated understanding of certain NOS concepts. On the other hand, there were also some participant teachers who failed to improve their 'naïve' or 'limited' views of science at the end of the summer science camp. In fact, only a few of the teachers managed to transform their 'naïve' or 'limited' views of science to 'informed' view of science at the end of the camp program. But rather, many of the teachers reached, at most, a 'partially informed' view of science. A fewer number of 'informed' views of science held by the participant teachers at the end of the summer science camp could possibly be attributed to the short nature of the camp program, which kept teachers from digesting the intense experiences offered to them in the camp program. Therefore, it would be more reasonable to conceive the summer science camps for teachers as complementary to the variety of their other learning experiences related to NOS concepts. In other words, the experiences offered to the teachers in the camp program seem to be insufficient by itself in helping all of them reach 'informed' conceptions of NOS. Thus, the change process initiated in the camp program should be continued further with teachers' engagement in meaningful experiences regarding NOS concepts. Among other strategies used to teach NOS, summer science camps might occupy an important place as a complementary approach in supporting teachers' NOS conceptions.

Limitations and Future Research

Not all participant teachers benefitted equally from the camp program. In that, some teachers definitely accomplished more progress than some others. The question of why some of the teachers experienced more improvement than some others does not have a readily available answer. The prior knowledge and beliefs of the learners definitely play a significant role in their subsequent learning experiences. The same is true when it comes to developing new understandings about NOS concepts. Teachers construct their own personal epistemological beliefs in connection with a variety of their unique life experiences. The strong bond of teachers'

NOS conceptions with their personal epistemological beliefs was evidenced by several research studies in the literature (e.g. Cho, Lankford, & Wescott, 2011; Koseoglu & Koksal, 2015; Marra & Palmer, 2005; Saylan, Bektas, & Oner-Armagan, 2015). Teachers “who have immature epistemological beliefs are more likely to also have immature beliefs of nature of science” (Cho, Lankford, & Wescott, 2011, p.313). Immature personal epistemological beliefs are thought to be one of the major obstacles in actualizing a conceptual change with teachers (Thoermer & Sodian, 2002). For instance, teachers “who adopt an absolutist epistemological stance will have difficulty in understanding the relation between theories and evidence” (Thoermer & Sodian, 2002, p.264). Developing ‘informed’ views of science by the participant teachers who held unsophisticated personal epistemological beliefs at the beginning of the camp program could be a difficult task to achieve in a relatively short period of time (a week in this case). Future research should seek to identify the teachers’ existing epistemological stance as part of the data collected at the start of the camp. The research studies to be conducted in the future would be helpful to unveil the link between teachers’ personal epistemological beliefs and their learning experiences of NOS concepts in short-term instructional interventions. The summer science camp presented in this study initiated a conceptual change process in many of the participant teachers’ minds. Creating a substantial change in teachers’ NOS conceptions, which are ultimately connected to their personal epistemological beliefs, might involve exposing them to more extended experiences. For instance, offering a follow-up learning opportunity to the participant teachers would allow them to reflect on their previous learning experiences and to internalise the newly formed conceptions. That is, short-term learning experiences of the teachers should be supported appropriately with the subsequent instructional interventions.

The participant teachers in this study were exposed to several learning experiences, some of which were more positive than others, in the camp program. Providing an elaborated description of the positive experiences of some teachers would be both informative and inspirational to other researchers and teachers. However, giving a comprehensive qualitative account of the exemplary cases was beyond the scope of this research study. Future research studies taking a closer look at the positive experiences of the teachers in a summer science camp would promise an important contribution to the education literature.

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Appendix A

Question-5 (Differences and Relationship between Theories and Laws)

Naïve View: Consider that a hierarchical relationship exists between scientific laws and scientific theories. As opposed to scientific laws, there is a very little evidence behind scientific theories. Think that once scientific theories are proven to be true with sufficient evidences, they become scientific laws. Assume that since scientific laws are supported with a bunch of evidence and tested numerous times by many different scientists, the truth represented by them is universally accepted and absolute.

Limited View: Express some correct statements about the description of scientific laws and scientific theories. Believe that scientific theories are supported with some evidences. However, still reserve a higher status to scientific laws than scientific theories due to the vast amount of evidence behind scientific laws. Think that scientific theories may undergo several changes as new evidences emerge. On the other hand, suppose that scientific laws are a highly durable piece of knowledge.

Partially Informed View: Provide a somewhat correct definition of both scientific laws and scientific theories. While scientific laws describe what happens in nature, scientific theories explain why it happens. Know that no ranking is existent between scientific laws and scientific theories because both of them are backed by considerable amount of evidences. However, assume that scientific theories still need some further refinement in order to become as much resistant to change as scientific laws.

Informed View: Identify that scientific laws and scientific theories are two distinct form of scientific knowledge. Therefore, consider that a hierarchical relationship between them is irrelevant. In other words, there is no such thing as turning of a scientific theory into a scientific law once it is proven. Know that whereas scientific laws provide a depiction or a formulation of the observed events in nature, scientific theories bring an inferred explanation to the underlying reasons of the natural events. Furnish some concrete examples about the distinction between scientific laws and scientific theories. Comprehend that like any other piece of scientific knowledge, both scientific laws and scientific theories are always open to change.

Appendix B

Sample Excerpts from Teacher Responses

QUESTION-1 **What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?**				
	Naïve	Limited	Partially Informed	Informed
Responses	Science involves using the scientific method to produce objective knowledge. Science aims to explain the observed events in nature. It is objective, systematic and cumulative.	Science is described as a body of scientific knowledge supported by strong evidences. Scientific knowledge is produced by following the scientific process consisting of repeatable experiments. Religion and philosophy differ from science with respect to their sole dependence on the specific thinker.	Science is a human endeavour to understand the natural events. The results offered by science need to be observable, questionable and provable. The evidences included in a specific scientific research study are highly debated in a scientific community. These activities are irrelevant in philosophy and religion.	Science is a way of understanding the world through making observations and conducting experiments. Scientific knowledge has to be supported with the empirical evidences. Until a law or a theory is refuted as a result of the discovery of new information or the reinterpretation of existing information, it is accepted as true knowledge. The acceptance of the new scientific knowledge happens with the negotiation of the scientific community.

Responses	Science consists of laws discovered by using the scientific method and accepted by all scientists. Science is objective and independent from the subjective ideas of the people. It should be free from the social and cultural values. The findings in science should be supported by carefully designed experiments.	Science is a body of knowledge generated from objective and provable information. Positive sciences like physics, chemistry and biology offer objective knowledge, which is repeatable by anyone with the same results. That distinguishes science from other disciplines like religion and philosophy.	Science is the end product of the research studies conducted to understand the events in the universe. Scientific research uses some peculiar methods to investigate the natural events. The findings in scientific studies are based on hard evidences. However, the arguments made in philosophy and religion rest solely on reasoning yet fail to provide any hard evidences.	Science is a process of searching for answers to the events occurring in nature. Curiosity drives the desire to understand the unknown. The process starts with asking a simple question and continues with devising specific methods to find an answer to the question. The empirical results obtained from the investigations are shared with the broad research community to get other scientists' approval. Once approved by the scientific community, the knowledge is registered as scientific until new information contradicting with it emerges.
QUESTION-2 **What is an experiment?**				
	Naïve	Limited	Partially Informed	Informed
Responses	Experiment might be considered as the trials and errors made to reach the scientific knowledge.	Experiment embraces all activities designed to test a supposition or a hypothesis.	Experiment is a controlled observation to prove the truthfulness of a hypothesis.	Experiment is to identify the changes in the results through manipulating some of the variables related to the research problem.
Responses	Experiment is the process of proving the truth in various environments. It simply gives an idea of whether the scientific knowledge at hand is accurate.	Experimenting is to prepare various apparatus to prove the correctness of a hypothesis offered to solve a problem.	Experiment is the act of explanation of an event using artificially constructed apparatus and following certain special methods.	Experiment is to measure the effect of the independent variables on the dependent variables, which aims to test the differences among groups with different characteristics.

QUESTION-3
Does the development of scientific knowledge require experiments?
• If yes, explain why. Give an example to defend your position.
• If no, explain why. Give an example to defend your position.

	Naïve	Limited	Partially Informed	Informed
Responses	Experiments are must in science because scientific knowledge has to be provable. This can only be possible with experiments.	Experiments should be conducted for the development of scientific knowledge. The correctness of scientific knowledge diminishes without conducting controlled experiments.	It depends. Using experiments is connected to the specific topic to be investigated in a scientific discipline. For instance, conducting an experiment is almost impossible in evolution topic due to extensive time requirements.	Adopting experimental research methods is not compulsory in producing or validating scientific knowledge. Observational data as well yields to scientific knowledge. For instance, other than observations, there is no other way of studying sun spots as we have no opportunity to travel to the sun.
Responses	Experiments are an inseparable part of science because they help us reach the universal results.	Experiments are definitely necessary for the development of knowledge. Without experiments, scientists do not get healthy results. For instance, pharmacy sector frequently conducts experiments to produce new medicines. Controlled experiments are the most important step to be taken to reach the reliable results in scientific research.	Experiments are necessary for the objectivity of scientific knowledge. Finding the shortcomings of an existing scientific theory requires using experiments. Using experiments enhances the accuracy of the scientific knowledge. However, this is not applicable to the fields of science using observational studies.	No, because scientific knowledge is not solely produced via experiments. Scientific knowledge is also produced by observations. In some specific areas of science such as astronomy, conducting an experiment is already irrelevant.

QUESTION-4
After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
If you believe that scientific theories do not change, explain why. Defend your answer with examples.
• If you believe that scientific theories do change:
(a) Explain why theories change?
(b) Explain why we bother to learn scientific theories?
Defend your answer with examples.

	Naïve	Limited	Partially Informed	Informed
Responses	Theories are open to change because they are indefinite knowledge not supported with the scientific evidences. Theories serve as a transition step to the scientific laws. Until becoming a scientific law, they are changed systematically.	Theories are the best explanations of the observations available in a certain period of time. They do change in time because they are unproven knowledge yet. As the new evidences are obtained or the errors are discovered in the existing data, the mistakes in theories are corrected to improve their reliability.	Although there exist strong evidences supporting the scientific theories, they are still not definite knowledge. That is why they are subject to change in the future. The advancement of technology and the emergence of new evidences necessitate the revisions to be made in the theories. Otherwise, the continuous progress in science stops at some point in time.	Theories do change in time. Scientific knowledge is always open to change. Otherwise, it would be no different than the dogmas. The change in scientific knowledge might occur due to the discovery of new evidences or reinterpretation of the existing information. The geocentric model of the universe proposed by Ptolemy was replaced by the heliocentric model supported by Copernicus as a result of the reinterpretation of the existing information.
Responses	Change is an inseparable aspect of theories because they are unproved ideas. They are not accepted by everyone yet. Once theories are proved by scientific methods, they turn into laws accepted by all scientists.	Scientific theories experience some changes as the time passes. The mistakes in a theory might be recognized later as the new experiments and observations are made. For instance, Dalton's theory of atom conceptualized the atom as an indivisible entity due to the lack of available data at the time.	With the emergence of new information, the theories might be changed partially or refuted completely. The historical development of the atomic theories is a good example for that. None of the atomic theories accepted to be true in the past is valid in today's world. This implies that the modern theory of atom might be revised in the future if it fails to explain the new evidences.	Scientific theories are subject to change. That is because they offer an explanation to an event with the perspective of the specific time period in which they were born. In time, the new technological innovations and the growing body of knowledge lead to developing better perspectives in explaining the scientific observations. Some theories are revised or refuted in relation to the developing knowledge base in time.

QUESTION-5
Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

	Naïve	Limited	Partially Informed	Informed
Responses	As opposed to a scientific theory, a scientific law is scientific knowledge, which has been proved definitely by many scientists. If a theory is proved in the future, it becomes a scientific law.	Scientific theories are open to change as conflicting information is discovered in the future. However, the same is not applicable to scientific laws. For example, theories about the atom have seen several changes since the time of Democritus. Newton's Laws of Motion has encountered no change since then.	A scientific law is not superior to a scientific theory. They both share the same level in the knowledge stair. While scientific laws are used to explain more concrete problems, scientific theories aim to explain more abstract phenomena.	A theory and a law is not the same thing in science. They both have different functions to fulfill. Scientific theories explain the underpinning reasons of scientific laws. While Newton's Law of Gravity provides a mathematical formulation of the gravity which makes the accurate calculations possible, Einstein's Theory of General Relativity actually brings an explanation to the source and the working mechanism of the gravity.
Responses	There is certainly a difference between a theory and a law in science. A scientific theory is neither proved nor falsified. On the other hand, a scientific law giving the same result under the same conditions is universally proved and definitive. For instance, Darwin's Theory of Evolution has not turned into a law due to the lack of definitive proofs. However, Newton's Law of Gravity is a universally accepted knowledge.	There exists several supporting evidence for scientific theories. However, scientific laws are a more durable piece of knowledge than scientific theories. Thus, in comparison to scientific theories, scientific laws are very resistant to the change.	I know that there is no hierarchical relationship between a theory and a law. That is, a theory after being proved does not turn into a law. However, as far as I know, unlike a scientific law, a scientific theory has still some missing parts to be filled with more evidences.	Scientific theories aim to explain the cause of the natural events. Scientific laws, on the other hand, formulate the effects of the natural phenomena. This allows scientists to make the precise calculations.

QUESTION-6
Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?

	Naïve	Limited	Partially Informed	Informed
Responses	I think scientists are so confident about the structure of the atom. Until the invention of the strong microscopes, scientists were not able to observe the atoms inside the matter. Ancient Greek philosophers had some philosophical arguments without concrete evidences about the existence of the atoms. Today, advanced technology provides us the opportunities to detect the atoms.	As of today, I think scientists are confident about what they know about the structure of the atom. However, this does not keep them from conducting new research studies on the topic. They still pursue the truth through searching for proving or disproving evidences. If they are faced with a new discovery one day in the future, they make the required changes in their thoughts accordingly.	Scientists are not sure about the true nature of the atom. For a long time, a bunch of ideas have been proposed about the structure of the atoms. The ones that explained the existing observations at the time have been retained and exposed to further tests. Being unable to observe the atom directly seems to be the biggest obstacle in front of delving into the true nature of the atoms.	Atoms as the building blocks of the nature are amazingly small structures. No device can ever achieve the direct observation of the subatomic particles. Our knowledge of the atoms is based on the indirect attributes of the atoms. Therefore, all theories of atom are models, which are considered to be the most successful explanation of the current available observations. This implies that we cannot treat the models as the ultimate truth.

Responses	Scientists are sure that the atoms exist as the building blocks of the matter. Following the scientific method, scientists have observed the atom with advanced microscopes. For a long time ago, the atom was conceived as the smallest indivisible unit of the matter. However, the discovery of the proton and neutron invalidated this conception of the atom. The technologic innovations in science eased the observation of the atom in laboratory conditions.	Scientists are certain about the structure of the atom based on the abundant amount of evidence that they obtained from the several different sources. However, more information gained by the emergence of new technologies might open new avenues in our understanding of the subatomic particles.	It is hard to say that the scientists are definitely sure about the structure of the atom. The atomic theories devised by several scholars such as Democritus, Dalton, Thompson, Rutherford and Bohr indicate that our knowledge of the atoms are not definite but improving as the new information emerges from different research studies. As we already know it, scientific knowledge is always open to modifications and theories of atom are not an exemption.	The information about the atom has changed many times historically. Giving a better explanation to the new information resulted in the modification of the existing theories of the atom. Nonexistence of a method for the direct observation of the atom and the uncertainty principle in the subatomic world keep scientists from reaching the ultimate truth about the atoms. The contemporary model proposed to describe the structure of the atom does not represent the ultimate reality but the best available explanation of the current information about the atom.

QUESTION-7
Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence do you think scientists used to determine what a species is?

	Naïve	Limited	Partially Informed	Informed
Responses	After conducting many research studies over a long period of time, scientists have distinguished each species from the others. Due to the fact that the discovery of the species has been exposed to rigorous scientific tests, they are confident about the accuracy of their classification of the species on earth.	There are certain criteria for similar organisms to be considered as a new species. Animals coming from a common ancestor and breeding with each other are accepted as the members of a peculiar species. For instance, a mull is not a species due to its infertile nature and its dissimilar parents.	Scientists identified the existing species based on the similarities and differences of the living organisms. Their breeding properties, DNA structures and living characteristics were taken into account in generating a definition of the species.	A species refers to the group of organisms having similar characteristics. It is not something that exists in the nature waiting to be discovered by scientists. But rather, scientists have created this classification with regard to the breeding practices, DNA structures, feeding habits and living conditions of the organisms. Scientists sometimes encounter problems in classifying new organisms which bear the characteristics of more than one species.

Responses	I think scientists are pretty sure about the classification of the species based on many experiments conducted with diverse animals. They identified the species as a result of producing fertile offspring when breeding. This is not possible by breeding two animals belonging to different species.	Scientists are confident about their discovery of diverse species because many scientists have been studying on the topic over a very long period of time. They have made several observations and experiments to test their ideas. However, if they discover a new kind of organism in the future, they might revise their classifications.	Scientists are still not sure about the classification of the species. Due to the tentative nature of the scientific knowledge, the species identified today may be revised in the near future depending on the discovery of the new cases. The existing definition of the species was produced by studying on very large samples. Repeating the same patterns in a consistent way allowed scientists to generalize their description of the species.	The concept of the species is a classification system generated by scientists to help them identify the living organisms in a simpler way. This implies that the classification system is open to change based on the discovery of the new organisms, which do not fit to the current classification system.

QUESTION-8 **It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?**				
	Naïve	Limited	Partially Informed	Informed
Responses	I think that happens due to insufficient data at hand. Observing the event is impossible because it occurred a very long time ago. Therefore, scientists produce different theories explaining it. If there were more data available, the results would be more accurate.	There is missing parts in science. The missing parts are filled with the imagination of the scientists. Different scientists might fill the missing parts differently and that is normal.	Each group of scientists might interpret the same data in a different way. Personal differences play an important role in reaching the conclusions. The results depend on the creativity of the scientists.	Using same data yet reaching different conclusions is quite possible in this case because scientists look at the world from different lenses. This makes them to interpret the data in peculiar ways. Scientists graduated from different schools might develop distinct mindsets. In their research projects, some scientists might cross the borders of traditionally approved theoretical frameworks and approach the available data with different perspectives. Einstein looked at the issue with a different perspective and revolutionized the physics.

Responses	In both cases, I believe that there is still missing parts. The existing evidences might fit both theories equally well. However, one theory will eventually be supported more than the other as more specific data is retrieved. Alternatively, it is possible that the new data might invalidate the claims of both theories and lead to emergence of new theories.	The reason for having different conclusions from the same data is that both groups of scientists use their imagination and interpret the event in a different way. It is like people looking at a picture and seeing different aspects of it. İmagination makes the difference.	Even if scientists use the same data to explain the event, their distinct backgrounds might influence their decisions. For example, the relationship between carbon dioxide release and global warming is interpreted in a different way by different scientists. This generally results from the subjective judgments of the scientists based on their diverse backgrounds.	Even if the data used by scientists in their research studies is alike, the method that they follow in their investigation and the technique that they use in interpreting the available data differ from one to another. In addition, the theoretical perspectives adopted by different research groups might emerge as the contributing factor to the different conclusions supported by the scientists.

QUESTION-9

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.

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

	Naïve	Limited	Partially Informed	Informed
Responses	Science is universal. It is independent from the society, politics and culture. Therefore, science is not influenced by them. Science is a way of discovering the natural processes. The nature is the same for everybody.	Scientific knowledge is universal. It might be affected from the cultural values at the beginning stages of the inquiry process such as determining the specific problem to investigate. However, at further stages of the investigation especially in the analysis of the available data, science is not influenced by the culture. Scientific research studies alike conducted in different cultures yield the same results	I think that science does not reflect the society but interacts with it. If science reflects the values of the society, its development is hindered. On the other hand, if it becomes completely free from the values, it cannot find itself a secure place in the society. Therefore, science is influenced by social and cultural values, yet at the same time it is universal.	Scientific knowledge is influenced by the society in which it has developed. That is because scientists as well are a part of the society and it is impossible to be free from the values of the society.

Responses	I believe the universality of the science. Every one regardless of belonging to the Islam, Christianity or Judaism believes that the matter is composed of atoms. Science does not offer solutions solely to the problems of a specific culture but it serves to all of humanity.	For years, science has been influenced by the society and culture. However, this is a big limitation of science. Science should be the universal. Objective truth should be unveiled without any extraneous influence. We can trust science as long as it keeps its objectivity.	Science is influenced by the societal and cultural values. However, the cultural and moral values of the society cannot put rigid borders around science. The knowledge gained by scientific research studies addresses all cultures at the same time without any discrimination. This is what makes science universal.	I believe that the science reflects social and cultural values because scientists are also humans living in a society and having certain beliefs. In terms of responding to the specific needs of their society and attempting to prove the truthfulness of their beliefs, the research studies conducted by scientists might be affected.

QUESTION-10
Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
• If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.
• If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

	Naïve	Limited	Partially Informed	Informed
Responses	Scientists use their imagination and creativity. However, they do this at the stage of posing a question worth to inquire. Apart from this, scientific knowledge is free from imagination and creativity. It is only related to the scientific truth. It should be objective and universal. Following the steps of the scientific method will ensure the objectivity of the results.	Scientists use their imagination and creativity in the investigation process. They do this especially in planning their observations and designing their experiments. In interpreting the data, they stay away from their imagination and creativity as much as possible.	Scientists design research studies to find an answer to their questions. In doing so, imagination and creativity play an important role. Imagination and creativity encourage them to try new ways to solve the problems. However, the results of the study should be solely based on the data collected objectively with no imagination and creativity. This ensures that the results come from the data but not from pure imagination.	Scientists definitely use their imagination and creativity in their research studies. This occurs at every stages of the investigation from deciding the research problem to collecting data to inferring the results. Imagination and creativity are the two of the most fundamental attributes of a scientist because scientists should have the ability to develop different perspectives in producing the scientific knowledge. Einstein's relativity theory can be given as a good example to show the importance of imagination and creativity in the scientific inquiry process.

Responses	At the phase of devising a hypothesis and producing a solution to the problem, imagination and creativity are used by scientists. However, imagination and creativity should not be used in observations, collecting data and evaluating the results. The study should be as objective as possible.	Without imagination and creativity, the progress made in science would not be possible. Imagination and creativity is present at the beginning stage of the scientific research. However, the results of the scientific research do not contain any imagination and creativity.	Scientists use their imagination and creativity in their scientific research studies. Imagination and creativity are used more at certain phases of the research than some others. For instance, interpreting the available data involves utilizing more imagination and creativity. Collecting data, on the other hand, includes less imagination and creativity.	Scientists certainly use their imagination and creativity in their research projects. They do this in every stages of their investigation process. Scientists follow certain methods in their research studies but these methods are not like recipes. Their imagination and creativity are always in charge of their research designs.