INVESTIGATION OF THE PRESERVICE SCIENCE TEACHERS' VIEWS ON NATURE OF SCIENCE

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ABSTRACT

INVESTIGATION OF THE PRESERVICE SCIENCE TEACHERS' VIEWS ON NATURE OF SCIENCE

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The aim of this study is to investigate the views of preservice science teachers on nature of science (NOS). A total of 166 preservice science teachers participated in the study. A 21-item "Views on Science-Technology-Society (VOSTS)" instrument, translated and adapted into Turkish, were utilized to assess participants' views on the nature of science. The VOSTS (Aikenhead, Ryan and Fleming, 1989) is a pool of 114 empirically developed multiple-choice items with nine categories. In this study, 21 item selected from the epistemology of science category corresponded to the purposes of the assessment. In order to understand participants' views on nature of science in depth, semi-structured interviews were also conducted by 9 volunteer preservice science teachers.

The results gave a picture of the preservice science teachers' views on nature of science. Results of this study revealed preservice science teachers' misconceptions on nature of science. Their views are mostly traditional on the nature of science. Results of the study indicated that preservice science teachers held traditional views (naive) regarding the definition of science; the nature of scientific models; the relationships between hypotheses, theories, and laws; fundamental assumptions for all science; the scientific method; uncertainty in scientific knowledge; epistemological status of scientific knowledge; coherence of concepts across disciplines. On the other hand participants have contemporary views (realistic) on the nature of observation; the nature of classification schemes; the tentativeness of scientific knowledge; cause and effect relationship. Analysis of interviews also supported these findings and gave a deep insight on preservice science teachers' views on nature of science.

Keywords: Views on nature of science, preservice science teachers, scientific knowledge, scientific method, misconceptions.

ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ BİLİMİN DOĞASI HAKKINDAKİ GÖRÜŞLERİNİN ARAŞTIRILMASI

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Bu çalışmanın amacı fen bilgisi öğretmen adaylarının “bilimin doğası” (BD) hakkındaki görüşlerini araştırmaktır. Çalışmaya 166 fen bilgisi öğretmen adayı katılmıştır. Katılımcıların “bilimin doğası” hakkındaki görüşlerini değerlendirmek için Aikenhead, Ryan ve Fleming (1989) tarafından deneysel yolla geliştirilen, dokuz kategoriden ve 114 çoktan seçmeli sorudan oluşan “Bilimin Doğası Hakkındaki Görüşler” anketi kullanılmıştır. Bu çalışmada, değerlendirmenin amacına uygun olarak bilimin doğası bölümünden 21 soru seçilerek Türkçe’ye çevrilmiş ve adapte edilmiştir. Katılımcıların bilimin doğası hakkındaki görüşlerini daha detaylı incelemek amacıyla 9 fen bilgisi öğretmen adayının katıldığı görüşmeler yapılmıştır.

Sonuçlar, öğretmen adaylarının bilimin doğası konusundaki birçok kavram yanılgılarına sahip olduklarını göstermektedir. Bilimin doğası ile ilgili kavramların çoğunda geleneksel bakış açısına sahiptirler. Katılımcıların bilimsel gözlemler; sınıflandırma tekniklerinin doğası; bilimsel bilginin değişebilirliği ve sebep-sonuç ilişkileri gibi konularda çağdaş (gerçekçi) görüşlere sahip olduklarını gösterirken bilimin tanımı; bilimsel modellerin doğası; hipotezler, teoriler ve kanunlar arasındaki ilişkiler; bilimsel yöntem; bilimin temel varsayımları; bilimsel bilginin belirsizliği; bilimsel bilginin epistemolojik durumu ve disiplinlerin arasındaki ilişkiler hakkında geleneksel görüşlere sahip olduklarını ortaya koymuştur. Fen bilgisi öğretmen adayları ile yapılan görüşmelerin analizi de bu bulguları desteklemiştir.

Anahtar kelimeler: Bilimin doğası hakkında görüşler, fen bilgisi öğretmen adayları, bilimsel bilgi, bilimsel yöntem, kavram yanılgıları.

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CHAPTER 1

INTRODUCTION

There is not a consensus on how to define “science education.” Good, Herron, Lawson, and Renner (1985) defined science education as the discipline devoted to discovering, developing, and evaluating improved methods and materials to teach science, i.e., the quest for knowledge, as well as the knowledge generated by that quest. According to them a central concern of science education should be developing a better understanding of how scientists and people in general learn to quest for knowledge in order to help children learn. On the other hand, Yager (1985) claimed that to limit science education to discovering, developing, and evaluating “improved methods and materials for teaching science” makes science education “administrative”-less than a discipline- an inquiry without a domain of its own. Such a limited definition identifies the task of the science educators’ one of transmitting what scientists know to students of varying ages. Yager (1984) defined science education as; the discipline concerned with the study of the interaction of science and society- i.e. the study of the impact of science upon society as well as the impact of society upon science. According to him their interdependence becomes a reality and the interlocking concept for the discipline. In Yager’s opinion, research in science education centers upon this interface.

Scientific literacy is commonly portrayed as the ability to make informed decisions on science and technology- based issues and is linked to deep understanding of scientific concepts, the processes of scientific inquiry, and the **nature of science** (Bell, Blair, Crawford & Lederman, 2003).

Science education reform brought scientific literacy into the central point of the science education goals. Laugksch and Spargo (1996) stated that scientific literacy has received much attention in the last decade, particularly in the United States and Britain. Widespread scientific literacy of individuals is increasingly seen as being of vital importance for a number of different reasons-scientific, economic, ideological, intellectual, and aesthetic. Bybee, Powel, Ellis, Giese, Parisi, and

Singleyton (1991) explained that the features of a scientifically and technologically literate person understand those; science and technology are the products of culture within which they develop; the roles and effects of science and technology have differed in different cultures and in different groups within these cultures; technology and science are human activities that have creative, affective and ethical dimensions; and they base decisions on scientific and technological knowledge and process.

A scientifically literate individual is commonly portrayed as one who makes informed decisions within a science/technology context by drawing upon their rich scientific knowledge, such as an understanding of the concepts, principles, theories, and processes of science (Abd-El-Khalick, Bell & Lederman, 1998). The achievement of scientific literacy for individuals is viewed by many science educators as the educational solution to the many economical, social, and environmental challenges of the 21st century (Eisenhart, Finkel & Marion, 1996; cited in Moss, Abrams & Robb, 2001).

It is widely believe that understanding of the nature of science is an important objective in most science education curricula that are intended to promote scientific literacy. Lederman (1992) observed that the development of an adequate understanding of the nature of science or an understanding of science as a way of knowing continues to be advocated widely as a desired outcome of science teaching. Many contemporary science educators agree that encouraging students' understanding of the nature of science, its presuppositions, values, aims, and limitations should be central goal of science teaching (McComas, Clough & Almazroa, 1998).

The nature of science has been defined in numerous ways. Abd-el-Khalick, Bell and Lederman (1998, p.418) stated 'typically, the nature of science has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge". According to the Lederman (1986), nature of science mostly commonly refers to the values and assumptions inherent to scientific knowledge, for example, it is based upon the answers to such questions as: 'Is scientific knowledge moral or amoral?", 'Is it tentative or absolute?", 'Is scientific knowledge a product of human imagination or not?". So, individual responses to such questions can be presumed to constitute individual conceptions of the nature of science (Lederman, 1986).

The goal of helping students develop adequate conceptions of nature of science (NOS) has been agreed upon by most scientists, science educators, and science education organizations during the past 85 years (Abd-El-Khalick, Bell & Lederman, 1998). At present, despite their varying pedagogical or curricular emphases, agreement among the major reform efforts in science education [American Association for the Advancement of Science (AAS), 1990, 1993; National research Council (NRC), 1996] centers on the importance of enhancing K-12 students' conceptions of NOS. However, the achievement of this long-espoused goal has been met little success. Research has consistently shown that students' NOS views are not consistent with contemporary conceptions of the scientific endeavor (Akerson, Abd-El-Khalick & Lederman, 2000).

According to Lederman (1998), the general community of philosophers and historians of science can accept that: 'the characteristics of the scientific enterprise corresponding to a level of generality are that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), necessarily involves human inference, imagination, and creativity (involves the invention of explanations), and socially and culturally embedded. Three additional important aspects are the distinctions between observation and inference, the lack of a universal recipe like method for doing science, and the functions of and relationships between scientific theories and laws. These NOS aspects have been emphasized in recent science education reform documents in the USA (e.g., AAAS, 1990, 1993; Millar & Osborne, 1998; NRC, 1996; cited in Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). These characteristics of scientific knowledge are explained as following by Lederman, Abd-El-Khalick, Bell and Schwartz (2002):

The Empirical Nature of Scientific Knowledge: *Science at least partially based on observations of the natural world, and "sooner or later, the validity of scientific claims is settled by referring to observations of phenomena" (AAAS, 1990, p.4). However, scientists do not have direct access to most natural phenomena.*

Observations of nature are always filtered through our perceptual apparatus and/or intricate instrumentation, interpreted from within elaborate theoretical frameworks, and almost always mediated by a host of assumptions that underlie functioning of scientific instruments.

Observations, Inference, and Theoretical Entities in Science: *Students should be able to distinguish between observation and inference. Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses) and about which observes can reach consensus with relative ease. For example, objects released above ground level tend to fall to the ground. By contrast, inferences are statements about phenomena that are not directly accessible to the senses. For example, objects tend to fall to the ground because of gravity. The notion of gravity is inferential an the sense that it can be accessed and/or measured only through its manifestations or effects, such as the perturbations in predicted planetary orbits due to interplanetary attractions, and the bending of light coming from the stars as it rays pass through the sun's gravitational field. An understanding of the crucial distinction between observation and inference is a precursor to making sense of a multitude of inferential and theoretical entities and terms that inhabit the worlds of science. Examples of such entities include atoms, molecular orbital, species, genes, photons, magnetic fields, and gravitational forces (Hull, 1998, p.146)*

Scientific Theories and Laws: *Scientific theories are well-established, highly substantiated, internally consistent systems of explanations (Suppe, 1977). Theories serve to explain large sets of seemingly unrelated observations in more than one field of investigation. Theories cannot be directly tested. Only indirect evidence can be used to support theories and establish their validity. Scientists derive specific testable predictions from theories and check them against tangible data. An agreement between such predictions and empirical evidence serves to increase the level of confidence in the tested theory.*

Closely related to the distinction between observation and inference is the distinction between scientific theories and laws. In general, laws are descriptive statements of relationships among observable phenomena. Boyle's law, which relates *the pressure of a gas to its volume at a constant temperature, is a case in point. Theories, by contrast, are inferred explanations for observable phenomena or regularities in those phenomena. For example the kinetic molecular theory serves to explain Boyle's law. Students often (a) hold a simplistic, hierarchical view of the relationship between theories and laws whereby theories become laws depending on the availability of supporting evidence; and (b) believe that laws have a higher status than theories. Both nations are inappropriate. Theories and laws are different kinds of knowledge and one does not become the other. Theories are as legitimate a product of science as laws (Figure 1.1).*

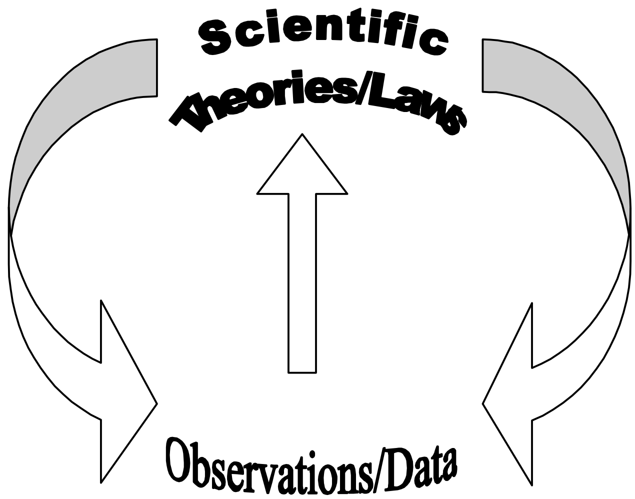

Figure 1.1. Relationship between Scientific Theories/Laws and Observations/Data (Lederman et al. 2002)

The Creative and Imaginative Nature of Scientific Knowledge: *Science is empirical. The development of scientific knowledge involves making observations of nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. Science, contrary to common belief, is not a lifeless,* *entirely rational, and orderly activity. Science involves the invention of explanations and theoretical entities, which requires a great deal of creativity on the part of scientists. This aspect of science, coupled with its inferential nature, entails that scientific entities such as atoms and species are functional theoretical models rather than faithful copies of reality.*

The Theory-Laden Nature of Scientific Knowledge: *Scientific knowledge is theory-laden. Scientists' theoretical and disciplinary commitments, beliefs, prior knowledge, training, experiences, and expectations actually influence their work. All these background factors form a mindset that affects the problems scientists investigate and how they conduct their investigations, what they observe (and do not observe), and how they interpret their observations. This (sometimes collective) individuality or mindset accounts for the role of theory in the production of scientific knowledge. Contrary to common belief, science never starts with neutral observations (Popper, 1992). Observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems, which are derived from certain theoretical perspectives.*

The Social and Cultural Embeddedness of Scientific Knowledge: *Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion.*

Myth of The scientific Method: *One of the most widely held misconceptions about science is the existence of the scientific method. The modern origins of this misconception may be traced to Francis Bacon's Novum Organum (Bacon, 1996), in which the inductive method was propounded to guarantee "certain" knowledge. Since the 17th century, inductivism and several other epistemological stances that aimed to achieve the same end (although in those latter stances the criterion of certainty was either replaced with notions of high probability or abandoned altogether) have been debunked, such as Bayesianism, falsificationism, and hypothetico-deductivism (Gillies, 1993). Nonetheless, some of those stances,* *especially inductivism and falsificationism, are still widely popularized in science textbooks and even explicitly taught in classrooms. The myth of the scientific method is regularly manifested in the belief that there is a recipelike stepwise procedure that all scientists follow when they do science. This notion was explicitly debunked: There is no single scientific method that would guarantee the development of infallible knowledge (AAAS, 1993; Bauer, 1994; Feyerabend, 1993; NRC, 1996; Shapin, 1996). It is true that scientists observe, compare, measure, test, speculate, hypothesize, create ideas and conceptual tools, and construct theories and explanations. However, there is no single sequence of activities (prescribed or otherwise) that will unerringly lead them to functional or valid solutions or answered, let alone certain or true knowledge.*

The Tentative Nature of Scientific Knowledge: *Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge, including facts, theories, and laws, is subject to change. Scientific claims change as new evidence, made possible through advances in thinking and technology, is brought to bear on these claims, and as extant evidence is reinterpreted in the light of new theoretical advances, changes in the cultural and social spheres, or shifts in the directions of established research programs. Tentativeness in science does not arise solely from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded. There are compelling logical arguments that lend credence to the notion of tentativeness. Indeed, contrary to common belief, scientific hypotheses, theories, and laws can never be absolutely proven irrespective of the amount of supporting empirical evidence (Popper, 1963). For example, to be proven, a law should account for every instance of the phenomenon it purports to describe. It can logically be argued that one such future instance, of which we have no knowledge whatsoever, may behave in a manner contrary to what the law states. Thus, the law can never acquire an absolutely proven status. This equally holds in the case of theories.*

1.1. Significance of the study

Saunders (2001) stated that one major outcome which has remained prominent in the professional science education literature for many decades deals with students' understanding of basic notions about the methodology of science. This understanding (of the "nature of science") is thought to be essential future citizens. It is argued that in order to grasp the role of science in society, and to be intelligent decision makers in democracy, students need to acquire a meaningful understanding of the nature of science including its potential and its limitations (Collette and Chiappetta, 1984; cited in Saunders 2001).

Students are the future citizens who will run the country and make some of the most important decisions affecting many lives. Therefore, they must be aware of the nature of science and technology. It is clear that teachers who want to increase students' understanding of the nature of science and thus increase their scientific literacy must pay careful attention to what they say and do in the classroom and to the kind of classroom climate they establish (Lederman, 1990). There appears to be an overt recognition that teachers cannot teach what they do not understand, and that simply possessing the desired knowledge does not ensure its effective communication to students (Lederman, 1992).

Although an understanding of the nature of science is considered to be one of the primary goals of science education for many years, previous studies show that both students and teachers have inadequate conceptions about the nature of science. Researchers argued that the main reason for students' inadequate conception is the inadequate conceptions of science teachers who are the responsible persons to develop such an understanding in their students. On the other hand, in Turkey, understanding of the nature of science as one of the most important aspect of science teaching, have not been investigated enough yet. Therefore, this study will also be a step revealing preservice science teachers' views on the nature of science in Turkey.

The results of Third International Mathematics and Science Study (TIMSS, 1999) showed some alarming results for our country in terms of science education. According to the results of this study, there is much more emphasis on scientific knowledge, basic science facts and concepts than the application of science, designing and conducting scientific investigations. The science topic in the intended curriculum is 95% for Turkey. This is about 86% in US, 71% in England, 67% in Italy, and 38% in Belgium. This means that we intended to teach but we could not. TIMSS also investigated the emphasis on several approaches and processes given in different countries. According to this study, emphasis given on to nature of science in Turkey evaluated as moderate. Major emphasis was given to this point in many other countries such as Canada, Finland, and Netherlands etc. It is obviously seen that our science education needs fundamental changes. It is clear that science teachers are the key factors for changes in education. For that reason, the present study aimed to determine the views of preservice science teachers' on nature of science issue, which is the basic goal of contemporary science education. The result of this study gives the opportunity to future studies to improve science education starting from the key elements, preservice science teachers, of the nature of science.

According to the findings of this study, current science teacher education programs may be modified in the direction for enhancing science teachers' understanding on the nature of science. Science teachers will find these views on nature of science results useful because the data reveal preconceptions harbored by preservice science teachers in Ankara. These data can guide the design of lessons or units. They also offer teachers a way of assessing their students' views on the nature of science.

CHAPTER 2

REVIEW OF LITERATURE

This chapter is devoted to the previous studies that have produced theoretical background of this study, instruments and studies developed and used for assessing views of nature of science.

2.1. Nature of Science (NOS) in Science Education

Future citizens in a democracy need to have a very fundamental knowledge of the nature of science in order to participate in intelligent debate and decision-making with respect to the many social issues arising from science and technology (Saunders, 2001). In order to grasp the role of science in society, and to be intelligent decision makers in democracy, students and teachers need to acquire a meaningful understanding of the nature of science including its potential and its limitations.

NOS refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge (Lederman, 1992). These characterizations nevertheless remain fairly general, and philosophers of science, historians of science, sociologists of science, and science educators are quick to disagree on a specific definition for NOS. Such disagreement, however, should not be surprising given the multifaceted and complex nature of the human endeavor we call science. Moreover, similar to scientific knowledge, conceptions of NOS are tentative and dynamic: These conceptions have changed throughout the development of science and systematic thinking about its nature and workings (Akerson, Abd-El-Khalick & Lederman, 2000).

A consensus view of nature of science objectives stated in eight international science standards documents (Table 2.1).

Table 2.1. Nature of Science Objectives (McComas, Clough & Almazroa, 1998, p.6)

Scientific knowledge while durable has a tentative character.
Scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism.
There is no one way to do science (therefore, there is no universal step-by-step scientific method).
Science is an attempt to explain natural phenomena.
Laws and theories serve different roles in science; therefore students should note that theories do not become laws even with additional evidence.
People from all cultures contribute to science.
New knowledge must be reported clearly and openly.
Scientists require accurate record keeping, peer review and replicability.
Observations are theory laden.
Scientists are creative.
The history of science reveals both an evolutionary and revolutionary character.
Science is part of social and cultural traditions.
Science and technology impact each other.
Scientific ideas are affected by their social & historical milieu.

While the frequency of particular student views regarding the nature of science from year to year, the following are some of the more significant misconceptions that regularly appear and must be addressed: science provides society with instruments and processes that improve daily life (i.e. science is equated with technology); the best scientists are always open-minded, logical, objective, and unbiased in their work; scientific theories become laws with enough evidence; a particular scientific method exist and this accounts for the success of science; science, if done well, provides absolute certainty; scientific ideas are exclusively and unambiguously determined by empirical data; and scientific knowledge is discovered (i.e., ignoring the inventive/creative/idealized character of science ideas) (Clough, 1997).

Misconceptions about science are most likely due to the lack of philosophy of science content in teachers education programs and the failure of such programs to provide real science research experiences for preservice teachers while another source of the problem may be the generally shallow treatment of the nature of science in the textbooks to which teachers might turn for guidance. Some of the myths, such as the idea that there is a scientific method, are most likely caused by the explicit inclusion of faulty ideas in textbooks while others, such as lack of knowledge of the social construction of scientific knowledge, are the result of omissions in texts (McComas, 1998).

In an attempt to provide a more realistic view of science and point out issues on which science teachers should focus fifteen widely-held, yet incorrect ideas about the nature of science:

Myth 1: Hypotheses become theories that in turn become laws.

Myth 2: Scientific laws and other such ideas are absolute.

Myth 3: A hypothesis is an educated guess.

Myth 4: A general and universal scientific method exists.

Myth 5: Evidence accumulated carefully will result in sure knowledge.

Myth 6: Science and its methods provide absolute proof.

Myth 7: Science is procedural more than creative.

Myth 8: Science and its methods can answer all questions.

Myth 9: Scientists are particularly objective.

Myth 10: Experiments are the principal route to scientific knowledge.

Myth 11: Scientific conclusions are reviewed for accuracy.

Myth 12: Acceptance of new scientific knowledge is straightforward.

Myth 13: Science models represent reality.

Myth 14: Science and technology are identical.

Myth 15: Science is a solitary pursuit (McComas, 1998).

Duschl (1988, p.51) summarizes the classroom situation by saying that "the prevailing view of the nature of science in our classrooms reflects an authoritarian view; a view in which scientific knowledge is presented as absolute truth and as a final form." This view has been called scientism.

Nadeau and Desautels (1984) label epistemic view "scientism" and offer a five-category description of it:

1. Naive realism: Scientific knowledge is the reflection of things as they actually are.
2. Blissful empiricism: All scientific knowledge derives directly and exclusively from observation of phenomena.
3. Credulous experimentalism: Experimentation makes possible conclusive verification or hypotheses.
4. Blind idealism: The scientist is a completely disinterested, objective being.
5. Excessive rationalism: Science brings us gradually nearer the truth. (cited in Ryan, Aikenhead, 1992)

One vestige of logical positivism is the belief that scientific knowledge connects directly with reality, unencumbered by the vulgarity of human imagination, dogma or judgments. This ontological view is often associated with the idea that science finds absolute truth, and does so independently of the investigator's psychological and social milieu. Such "naive realism", as Nadeau and Desautels (1984) have called it, has been challenged by other philosophical positions. One example is the epistemological posture defined by Kuhn's (1970) disciplinary matrix which integrates scientific knowledge with the human setting in which it was generated. An epistemological stance is associated with consensus making. Knowledge becomes valid when it is accepted as fitting the prevailing knowledge system of qualified scientists. The ontological and epistemological labels are convenient for defining rather general and diametrically opposed orientations toward scientific knowledge (Aikenhead, 1987).

Yalvaç and Crawford (2002) stated that when we retrospectively scrutinize the science education curricula of Turkey, a country located between Eastern Europe and Western Middle East, it is apparent that Turkey followed many of the school reforms in the United States in the late sixties. Turkey imported many of the United State science education programs nearly without any detailed modification. In addition to Turkey, other countries including Canada, Australia, Israel, and Japan adopted those reform movements from the U.S. Some others such as Malaysia and

Nigeria adopted their school curricula from Britain (Blades, 1997). Many of these school reforms in the late sixties emphasized teaching science as content knowledge aligned with the logical positivist view of science. New reform movements in science education emphasize that students should understand science is tentative, subject to change, and not an absolute truth of nature; but rather it is our (human) own understanding. From this point of view, new reform documents, some of which explicitly and some others implicitly, propose that logical positivist understanding of science and its enterprise is misleading. Not only reform documents, but also many science philosophers, historians, and science education researchers emphasize that logical positivist view of science is not more than a dogmatic belief or a myth (Yalvaç & Crawford, 2002)

Tairab (2001) advocates that we need to explore the views held by preservice and in-service science teachers on nature of science and technology to reach the goals of science education on the classroom practices. Therefore studies about science teachers' and preservice science teachers' views on nature of science to develop scientific views consistent with the contemporary conception of the nature of science among researchers and science educators should continue.

2.2. Instruments Developed to Assess the Views on Nature of Science (NOS)

There are several instruments that have been developed to assess the views on nature of science. During the past 40 years, more than 20 standardized and convergent paper and pencil instruments have been developed to assess learners' NOS views. These instruments are composed of forced-choice items, such as agree/disagree, Likert- type, or multiple choice (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002).

According to Lederman et al. (1998), instruments with questionable validity (as measures of the nature of science) include the Science Attitude Questionnaire (Wilson, 1954), Facts About Science Test (Stice, 1958), Science Attitude Scale (Allen, 1959), Process of Science Test (BSCS, 1962), Inventory of Science Attitudes, Interests, and Appreciations (Swab, 1966), Science Support Scale (Schwirian, 1968), Test on the Social Aspects of Science (Korth, 1969), Science Attitude Inventory (Moore & Sutman, 1970), Science Inventory (Hungerford & Walding, 1974), Test of Science-Related Attitudes (Fraser, 1978), the Test Enquiry Skills (Fraser, 1980), and the Language of Science (Ogunniyi, 1982). Therefore, Table 2.2 presents a comprehensive list of more formal instrument constructed and validated to assess various aspects of the nature of science.

Table 2.2. Instruments on Nature of Science

Name of the instrument	Year	Developers
Test on Understanding Science (TOUS)	1961	Cooley & Klopfer
Science Process Inventory (SPI)	1966	Welch
Wisconsin Inventory of Science Processes (WISP)	1967	Scientific Literacy Research Center
Nature of Science Scale (NOSS)	1968	Kimball
Nature of Science Test (NOST)	1975	Billeh & Hasan
Views of Science Test (VOST)	1975	Hillis
Nature of Scientific Knowledge Scale (NSKS)	1976	Rubba
Conception of Scientific Theories Test (COST)	1981	Cotham & Smith
Views on Science-Technology-Society (VOSTS)	1987	Aikenhead, Fleming & Ryan
Nature of Science Survey	1990	Lederman & O'Malley
Modified Nature of Scientific Knowledge Scale (MNSKS)	1992	Meichtry
Pomeroy's Scale	1993	Pomeroy
Critical Incidents	1995	Nott & Wellington
BASSSQ	1997	Alridge, Taylor & Chen
A Model of NOS Questionnaire	2001	Moss& Robb
Nature of Science and Technology Questionnaire (NSTQ)	2001	Tairab
VNOS	2002	Lederman, Abd-El-Khalick, Bell & Schwartz

2.3. Students' Views of Nature of Science (NOS)

The studies conducted to assess students' views were performed in several levels of education; from primary school level to university level. Advocacy for students' understanding of science and its nature can be traced back to the early years of this century. Although at that time the phrase "understanding the nature of science" was not clearly stated, some elements and characteristic of science were noted as goals worth pursuing in science teaching (McComas, Almazroa, Clough, 1998).

Lederman (1992) stated that the first formal instrument to assess students' conceptions of NOS was developed by Wilson in 1954. In an investigation that was primarily an attempt to validate an instrument known as the Science Attitude Questionnaire (Wilson, 1954), a sample of 43 Georgia high school students was found to believe that scientific knowledge is absolute and that scientists' primary objective is to uncover natural laws and truths. Additionally, this small sample of student possessed relatively negative attitudes toward science.

In 1961, Klopfer and Cooley developed the Test on Understanding Science (TOUS) which was to become the most widely used paper-and-pencil assessment of students' conceptions. Using the TOUS and a comprehensive review of several nationwide surveys, Klopfer and Cooley concluded that high school students' understandings of scientific enterprise and of scientists were inadequate. Miller (1963), using TOUS, also found disturbingly inadequate student conceptions (Klopfer & Cooley, 1961; Miller, 1963; cited in Lederman, 1992).

In another comprehensive study, Mackay (1971) pre- and post-tested 1203 Australian secondary students spanning grades 7-10, using Test on Understanding Science (TOUS) instrument. He concluded that students lacked sufficient knowledge of the role of creativity in science; the function of scientific models; the roles of theories and their relation to research; the distinction among hypotheses, laws, and theories; the relationship between experimentation, models and theories, and absolute truth; the fact that science is not solely concerned with collection and classification of facts; what constitutes a scientific explanation; and the interrelationships among and the interdependence of the different branches of science (cited in Lederman 1992).

During the development of his instrument, the Nature of Scientific Knowledge Scale (NSKS), Rubba found that 30% of the high school student surveyed believed that scientific research reveals incontrovertible and necessary absolute truth. Additionally, most of the Rubba's sample believed that scientific theories, with consistent testing and confirmation, eventually mature into laws (Rubba & Andersen, 1978). In 1981, Rubba, Horner and Smith attempted to assess students' adherence to the "myth" and the "fable" with a sample of 102 high-ability seventh-and- eight grade students. They concluded that students on the whole tended to be "neutral" with respect to both. In addition to these, the students did not understand the nature of science well enough to appreciate the tentative nature of scientific laws and scientific theories were two distinct types of explanations.

The sampling of the study done by Aikenhead, Fleming, and Ryan (1987) was carried out by the Canadian International Association for the Evaluation of Educational Assessment (IEA) study. About 10,800 students enrolled in the study. Views on Science-Technology-Society (VOSTS) statements were used as the instrument. The study was performed to understand the high school graduates' beliefs about characteristics and limitations of the scientific knowledge. Almost half of the high-school graduates (45%) claimed that scientific models are epistemological rather than ontological. They emphasized the criterion of being helpful in understanding nature and discounted the possibility of models duplicating reality. Similar to this result, 44% of the students assumed an epistemological view of models. They argued that like scientific theories, scientific models can be changed in time. For another question three basic reactions were observed at students, the constructionist position that scientific knowledge does change (44%), the cumulative position that it does not change but is added to (31%), and somewhere in between these two positions (11%).

The sample of the study of Ryan (1987) was the same with the sampling of the study done by Aikenhead, Fleming, and Ryan (1987) which was carried out by the Canadian International Association for the Evaluation of Educational Assessment

(IEA) study. About 10,800 students enrolled in the study. VOSTS statements were used as the instrument. The study was done to understand the high-school graduates' beliefs about the characteristics of scientists. Results indicated several important points. Some of the responses indicated that an overwhelming majority of students felt that scientists should be concerned with the potential effects, especially the harmful effects, of their discoveries. They said that scientists are being responsible in their actions. On the other hand, students were able to make a distinction between a characteristic which would be required in carrying out science and the characteristics of scientists as human beings. Some students felt that honesty and objectivity, being necessary for the performance of science, might rub off on scientists who need not necessarily be inherently honest or objective. Others felt that scientists would leave these characteristics at work and would be much like other people in daily life. Another result was related with the gender distribution of Canadian students. Many respondents (30%), especially females, gave sociological reasons for the situation. Another group (15%) felt that there were genetic differences which made science less attractive to females. The third group (25%) felt that men and women were equally capable of being good scientists.

Another study was performed by Fleming (1987). The study was about the views about STS, the interaction among science, technology, and society. A sample of 10,800 students, who were in their graduating year of high school, was drawn in a stratified manner from across Canada as part of the International Association for the Evaluation of Educational Assessment study. Students were asked to respond statement concerning an STS topic in agree-disagree-do not understand format. Then they were asked to write their reasons for the choice. Statements were taken from VOSTS Form CDN-2. One of the results of the study was that unless specifically asked to do so, students do not differentiate between science and technology. Another finding is about the cause of the specific social problems. About 22% of student responses suggest that science and technology both cause and aggravate the specific social problems but 19% of the respondents presented the view that the proper use of science and technology rests with the people.

Similarly, Aikenhead (1987) investigated to monitor the high school graduates' beliefs about Science-Technology-Society topics, and to reexamine current assessment practices with an eye to their improvement. The sample was the same with the study of Fleming (1987) which was drawn in a stratified manner from across Canada as part of the International Association for the Evaluation of Educational Assessment Study. The results reported that Canadian students' responses to the question from the instrument called VOSTS. The questions dealt with the characteristics and limitations of scientific knowledge. Results showed the followings: a majority of Canadian high school graduates viewed scientific classification schemes as being more epistemological than ontological and almost all of the respondents believed that scientific knowledge tentative, but their reasons varied widely. A large proportion of students believed that social instructions within the scientific community can affect the knowledge that scientists discover. On the other hand almost half of the students believed there was no influence from the outside and thus the facts basically spoke for themselves.

In another study at that level performed by Lederman and O'Malley (1990). They investigated the students' perceptions of tentativeness in science. The sample consisted of 36 males and 33 females spanned grades 9-12. Students are enrolled in physical science, biology, chemistry, and physics classes. All students were asked to complete a seven item open-ended questionnaire concerned with their beliefs about the tentative nature of science during the second week of the school year. The same questionnaire was repeated during the final month of the school year. At the end, researchers reviewed the completed questionnaires and identified 20 students to participate in videotaped "follow-up" interviews. The data gathered during the pretest seem to indicate that the students, as a group, do not uniformly adhere to either an absolute or tentative view of scientific knowledge. In contrast to the pre-test, the results of the post-test more clearly adhere to the tentative view of scientific knowledge. In the interview part, all students correctly interpreted the intent of each of the questionnaire items. In conclusion, the study displayed that more care must be taken in the assessment of students' perceptions of science. Language is often used differently by students and researchers and this mismatch has almost certainly led to misinterpretations of students' perceptions in the past.

Ryan and Aikenhead (1992) performed a study on the students' preconceptions about the epistemology of science. The responses were come from grade 11 and 12 students (N>2000) to a selection of VOSTS items administered as a national survey in Canada. Items related the following issues: the meaning of science, scientific assumption, values in science, conceptual inventions in science, scientific method, consensus making in science, and characteristics of the knowledge produced in science. Ryan and Aikenhead, (1992) concluded that they confused science with technology, and were only superficially aware of the private and public side of science and the effect that values have on scientific knowledge. Moreover they reported that: about 46% held the view that science could rest on the assumption of an interfering deity; only 17% were certain of the inventive character of scientific knowledge; only 19% believed that models are actual copies of reality; only 9% chose the contemporary view that scientists "use any method that might get favorable results"; and 64% of students expressed a simplistic hierarchical relationship in which hypotheses become theories and theories become laws, depending on the amount of "proof behind the idea."

Griffiths and Barmen (1995) interviewed a total of 96 high school students individually to understand some general terms used to classify scientific knowledge. The students were from three different countries; Australia, United States, and Canada. Answer to the question "how do scientists get information?" showed considerable differences between the three groups. Seventy-five percent of the American students were very attracted to the traditional view of the practice of science as involving a relatively set sequence of events. American students formed such sentences; scientists formulate a hypothesis, set up control groups and experimental groups etc. In complete contrast, the Australian students, although making frequent reference to experiments, virtually never spoke in terms of the traditional scientific method mentioned above. Collectively, the responses of the Canadian students were intermediate between these extremes, with 30% of them being attracted to the traditional view. In answer to the question "does science change?" About 75% of the total sample expressed a belief that it does. As a result of this international study, some major differences and many commonalties were observed between the three groups of students involved in terms of beliefs in the underlying status of scientific knowledge.

Solomon, Scott, and Duveen (1996) reported a questionnaire study of British pupils' understanding of several aspects of the nature of science. The prime sample totaled nearly 800 pupils aged 14-15 years. Interviews with teachers and questionnaire were used for the study. It was seen that a strikingly relation between the class in which the pupils were taught and how they answered most of the questions. This shows what may be both the effect of the teacher on the pupils' views and also an indication of the relative effect of in-school and out-of-school knowledge. Previous studies (Brickhouse, 1989; Lederman and Zeidler, 1987) have also pointed to the overriding influence of the teachers' views of the nature of science on what their pupils come to believe, whether or not it is explicitly taught.

Moreover, a study of Meyling (1997) investigated that students showed significant interest in the nature of science. Two –thirds of the physics students who experiences instruction regarding epistemological issues showed interest in more epistemology. In contrast, only one-third of students not experiencing such instruction showed interest. Students in this study approved of NOS discussions and most indicated their epistemological conceptions had changed.

Ryder, Leach, and Driver (1997) studied to describe the views about the nature of science held by science students in their final year at the university. For interview study, 11 students were asked questions about the nature of science during the time they were involved a project work. Five stimulus questions were asked without reference to any particular scientific context. Many of the students showed significant development in their understanding of how lines of scientific enquiry are influenced by theoretical developments within a discipline, over the 5-8 months period of their project work. Study indicated that only a few students made statements relating to the social dimension of science despite the fact that they had the opportunity to do so in response to many of the five stimulus questions. Findings of the study also indicated that students in the sample tended to view knowledge claims in science as provable beyond doubt using empirical data alone.

Tsai (1997) was performed a study to acquire a better understanding of the interaction between scientific epistemological beliefs and learning orientations in a group of Taiwanese eight graders. After analyzing the questionnaire responses of an initial sample of 202 students, 20 students were selected for the interview part of the study. For the quantitative part of the study Pomeroy's questionnaire (1993) was used. The selected subjects were interviewed regarding their beliefs about science and their learning orientations. One of the finding of the study is; knowledge constructivist subjects tended to have more pragmatic views about the value of science and they were mainly motivated by their interest and curiosity about science, whereas knowledge empiricist subject were mainly motivated by performance on examinations.

Brickhouse, Dagher, Letts, and Shipman (2000) studied on the growth in students' understanding about the nature of astronomy in a one -semester collage course. In addition to student work collected for 340 students in the course, they also interviewed focus students three times during the course. The study showed that students in the class came with the misconception "the view that facts and laws are absolute, whereas theories and hypotheses are tentative." Brickhouse et al. (2000) suggested that studying students' views about the nature of science is best done in a context where it is possible to talk about particular theories or particular pieces of evidence.

Zeidler, Walker, Ackett, and Simmons (2000) studied on the relationships between students' conceptions of the nature of science and their reactions to evidence that challenged their beliefs about socio-scientific issues. This study involved 41 pairs of students that were identified from a larger sample of 248 students from 9th and 10th grade general science classes, 11th and 12th grades honor biology, honors science, and physics classes, and upper level collage preservice science education classes. During the first phase of the study, students were asked to respond to open-ended questions in order to assess their conceptions relating to the nature of science. During the second phase, students were presented with a socio-scientific scenario that required decisions based on their moral reasoning or ethical beliefs. In the third phase, pairs were constructed from different levels of variation about the subject. Then, they were allowed to freely interact, challenge, and question each other during the interview process. Findings showed that students' conceptions of nature of science ranged from theories as static and fixed to the idea that they change in quick response to social utility and technological advances. Status of scientific knowledge versus opinion, students' responses distinguished between the "subjectiveness" of opinion and the "objectivity" of scientific knowledge. In general, subjectiveness was equated with personal opinions whereas scientific knowledge was associated with proven, tested, or constructed knowledge. Students generally perceived connections between art and science in terms of the creativity. However, a distinction seems to be made between the "spirit" of art that is more directly linked to emotion "activity" and of science.

A study performed with higher levels of students was conducted by Moss and Robb (2001). They examined the pre-collage students' understanding of the nature of science and track those beliefs over the course of an academic year-is one of the many studies performed to assess the student conception of the nature of science. Students' conceptions of the nature of science were examined using a model of the nature of science developed for use in this study. Findings indicated participant hold fully formed conceptions of the nature of science consistent with approximately one-half of the premises set out in the model. Students hold more complete understandings of the nature of scientific knowledge than the nature of the scientific enterprise. Their conceptions remained mostly unchanged over the year despite their participation in the project-based, hands-on science course.

One of the studies performed at the early school levels was the study of Shiang and Lederman (2002). They examined the seventh grade Taiwanian students' conceptions of the nature of science (NOS). The students were engaged in a 1-week science camp with emphasis on scientific inquiry and nature of science (NOS). Results indicated that the majority of the participants had a basic understanding of the tentative, subjective, empirical, and socially and culturally embedded aspects of

NOS. There were no significant changes in students' views on NOS both before and after instruction.

2.4. Teachers' Views of Nature of Science (NOS)

Akerson et al. (2000) stated that researchers started to realize the role of teachers as the main intermediates of the science curriculum. More studies came to support the claim that teachers' understandings, interest, attitudes, and classroom activities influence student learning to a large extent (e.g., Merill & Butts, 1969; Ramsey & Howe, 1969). This realization turned researchers' attention toward assessing teachers' conceptions of NOS (Akerson et al., 2000).

According to Lederman (1992), if teaching is viewed as a purposeful and conscious act, a teacher must possess an adequate knowledge what she/he is attempting to communicate to students. Although much of the research on teachers' conceptions followed the emergence of research findings indicating the importance of the teacher, the first assessment of teachers' conceptions was actually conducted prior to any assessment of students' conceptions. Minesota high school teachers were asked to answer a total of eight questions on scientific method, and it was revealed that both groups of teachers possessed serious misconceptions. Anderson (1950) explained the results by suggesting that the teachers were too busy imparting factual information to their students to be interested and/or concerned about one of the most important objectives of science instruction (Lederman, 1992).

Akindehin (1988) has done a research on the effect of an instructional package on preservice science teachers' understanding of the nature of science and acquisition of science-related attitudes. The study was carried out in three steps. Firstly, the pretests were administered to students in two of the four groups. In the second step, students in the two treatment (experimental) groups attended a one-hour lecture in the Introductory Science Teacher Education (ISTE) –instructional package designed for the study which was expected that it would foster an understanding of the nature of science as well as the development of favorable science related attitudes in preservice science teachers- once a week throughout the first semester of the academic session. Finally, the post-test were administered. The Nature of Science Scale (NOSS) was used as pre-test and the Teacher Science-Related Attitude Scale (TESRA) was used as post- tests. TESRA was adapted by the investigator from two other instruments-The test of Science-Related Attitudes (TOSRA) and the Inquiry Science Teaching Strategies (ISTS). According to the ISTE, the course had nine units; forms and fields of scientific knowledge; nature of science; ways of scientists; class discussion; history of science; class experiment; a class discussion on science and superstition; a class discussion on the new light; a class discussion on the scientists at work. The results showed that preservice science teachers exposed to the ISTE acquired better understanding of the nature of science and more favorable science-related attitudes than those who were not exposed to the ISTE. In terms of science-related attitudes, preservice science teachers exposed to the ISTE were found to have acquired a more favorable attitude to scientific inquiry, enjoyment of science lessons and science for leisure.

In the study of Cobern (1989), American preservice science teachers' responses to the Kimball's Nature of Science Survey (NOSS) were used as a basis for analyzing the sense of the nature of science held by a group of Nigerian preservice science teachers. Between 1980 and 1983, the researcher routinely had his senior-level preservice science teachers at the University of Sokota, Nigeria, take NOSS as a way of introducing the subject of science philosophy and its relevance to the science classroom. Two apparent differences were noted from the study. The primary difference was that the Nigerian students were much more inclined to see science as a way of producing useful technology. Given the national interest of a developing nation this is an understandable perception and one common among government policy makers. The second distinctive of the Nigerian students' sense of nature of science had to do with the openness of science. These students perceived scientists as nationalistic and secretive about their work.

Using a case study approach Aguirre, Haggerty and Linder (1990) assessed 74 preservice secondary science teachers' conceptions of the NOS, teaching, and learning. Subjects were asked to respond to 11 open-ended questions about science, teaching of science, and learning of science. The result of the study showed that most individuals believed that science was either a body of knowledge consisting of a collection of observations and explanations or of propositions that have been proven to be correct. Approximately one-third of the preservice science teachers characterized learning as the "intake of knowledge." The researchers concluded that these preservice science teachers did not possess adequate conceptions of NOS and also there could be some connection between teachers' views on NOS and their conceptions of learning and teaching (Aguirre, Haggerty & Linder, 1990).

Rubba and Harkness (1993) developed the Teachers' Belief About Science-Technology-Society (TBA-STS) assessing science teachers' belief about the nature of science and technology by following the development steps of VOSTS. The TBA-STS results showed that large percentages of the preservice and inservice science teachers in the two samples held misconceptions about the nature of science and technology and their interactions within society. Examples of these include: conceptualizing science as a sequential set of steps commonly referred to as "the scientific method"; visualizing scientific hypotheses, theories, and laws in a developmental sequence; and not distinguishing between science and technology. In addition, while they generally recognized the existence of interactions among science, technology and society, neither the preservice nor inservice science teachers were able to explicate those relationships (Rubba & Harkness, 1993).

Pomeroy (1993) investigated how scientists and teachers view the nature of science, scientific method, and related aspects of science education. The samples consisted of volunteers who filled out the survey in response to a written appeal. The mailing went to a group of Alaskan research scientists and secondary science and elementary teachers in Alaskan cities. A fifty-item survey was prepared in agree-disagree statements. The results showed that men in the samples fell into traditional patterns more than women. Surprisingly, the results also displayed that traditional views were expressed most strongly by scientists, next by secondary science teachers, and least by elementary teachers in this study.

Abd-El-Khalick and BouJaoude (1997) described the knowledge base of a group of science teachers in terms of their knowledge of the structure, function, and development of their disciplines, and their understanding of the nature of science.

The study also aimed to relate teachers' knowledge base to their level of education, years of teaching experience, and the class levels that they teach. Twenty inservice science teachers were selected to respond to a modified version of the VOSTS questionnaire to assess their understanding of the nature of science. The teachers constructed concept maps and were interviewed. The concept maps were scored and interviews analyzed to assess teachers' knowledge of the structure, function, and development of their disciplines. At the end of the study it was found that teachers held several naive views about the nature of science and did not demonstrate adequate knowledge and understanding of the structure, function, and development of their disciplines. Moreover, the teachers' knowledge base did not relate to their years of teaching experience, the class levels that they teach, and their level of education.

Botton and Brown (1997) carried out a study with a selection of Views on Science-Technology-Society (VOSTS) items. They wanted to ascertain the responses from a group of preservice postgraduate certificate of education students on a test-retest process. They also aimed to test the reliability of part of the instrument and analyze the responses and discuss further some aspects of the nature of science with respect to the items and responses. It was administered to a group of 29 postgraduate trainee science teachers. Two sections of the VOSTS were addressed: defining science and technology; and epistemology. According to the test-retest criterion, only 3 items from defining science and 17 from epistemology were seemed as reliable. Results have similarities with some other studies in some parts. For example, defining technology produced a variety of responses. The majority of the respondents defined technology as the application of science. Most appreciated the tentativeness of scientific knowledge but the difference between hypotheses, laws, and theories was not appreciated.

Haidar (1999) investigated Emirates pre-service and in-service views about the nature of science. A questionnaire was developed and administered to 31 female pre-service science teachers, and 224 in-service chemistry teachers. The questionnaire covered five aspects of the nature of science identified by Palmquist and Finley (1997). These are scientific theories and models; role of a scientist;

scientific knowledge; scientific method; and scientific laws. The results indicated that Emirates teachers' views are nei ther clearly traditional nor clearly constructivist-they held mixed views about the nature of science. The study attributed the existence of the traditional views to historical reasons and the educational system. The presence of constructivist views was attributed to religious factors, where some of students' religious beliefs agree with some constructivist views.

Akerson, Abd-El-Khalick, and Lederman (2000) assessed the influence of a reflective, explicit, activity-based approach to nature of science instruction undertaken in the context of an elementary science methods course on preservice teachers' views of some aspects of NOS. These aspects included the empirical, tentative, subjective (theory-laden), imaginative and creative, and social and cultural NOS. Participants were 25 undergraduate and 25 graduate preservice elementary teachers enrolled in two sections of the investigated course. An open-ended questionnaire coupled with individual interviews was used to assess participants' NOS views before and at the conclusion of the course. The majority of the participants held naive views of the target NOS aspects. Post instruction assessments indicated that participants made substantial gains in their views of some of the target NOS aspects. Less substantial gains were evident in the case of the subjective and social and cultural NOS. The results of the present study supported the effectiveness of explicit, reflective NOS instruction.

Tairab (2001) investigated to explore the views held by pre-service and in-service science teachers regarding the nature of science and technology. It was a part of a large-scaled project. The study was particularly on the characteristics of science and technology; the aim of science and scientific research; the characteristics of scientific knowledge; and the relationship between science and technology. The sample of the study consisted of 95 respondents (41 preservice science teachers and 54 inservice science teachers) drawn from two groups of science teachers by convenience sampling. The data were collected using the Nature of Science and Technology Questionnaire (NSTQ). Results indicated that generally pre-service and in-service science teachers have comparable views in relation to the nature of science and technology. The participants displayed mix views regarding science as content oriented or process oriented. Respondents viewed technology as an application of science. Most of the participants regarded science as explanatory and interpretative of nature.

The work of Craven, Hand, and Prain (2002) stated the processes and outcomes of practices in a preservice, elementary science method course. The course was designed to fathom existing student perceptions of the nature of science and move students from holding individually constructed, typically limited views on the nature of science towards more rich, publicly negotiated views. In the course of 15 weeks, 27 preservice elementary students engaged in a series of individual collaborative exercises that required them to explore their tacit and explicit knowledge about the nature of science. The data were analyzed using the interpretative-descriptive approach. Analyses revealed notable, positive changes in the language students used to describe both the nature and structure of the scientific enterprise.

Although a large research tradition has developed around the conceptions of nature of science in other countries, less has been done in Turkey. Bilgiç (1985) investigated the effectiveness of inquiry-oriented laboratory on students' understanding of the nature of scientific knowledge. The subjects of the study were the Middle East Technical University Science Education Department students taking the freshman physics course. For this study Nature of Scientific Knowledge Scale (NSKS) was used. The results showed significant changes on understanding of scientific knowledge of inquiry oriented laboratory students'.

Yakmacı (1998) investigated the Turkish prospective and inservice science teachers' views on nature of science. She used 18 selected items from VOSTS item pool. The results of the study showed that on some points such as the nature of classification schemes, tentativeness of scientific knowledge, the scientific approach in the investigations science teachers held contemporary views. On the other hand they have unrealistic views on many points; definition of science, the nature of observation, the nature of scientific models and some other characteristics of nature of science.

Another study from Turkey was performed by Yalvaç and Crawford (2002). They aimed to explore the graduate and undergraduate science education students' conceptions of the nature of science, in Middle East Technical University (METU). The participants of the study include 25 undergraduate and graduate science education students enrolled in the Science Education Program in METU, Ankara. For this study a questionnaire, which had been adapted from previous studies (e.g.Schwartz, Lederman, & Crawford, 2000) was used in this study. Findings of the study suggested that the majority of the participants hold views of nature of science aligned with logical positivism-a content oriented image of science. More than half of the Turkish students (71%) thought theories are subject to change but laws do not change.

Similarly, Macaroglu, Tasar and Cataloglu (1998) assessed the Turkish preservice elementary science teachers' beliefs about the nature of s cience using The Beliefs about Science and School Science Questionnaire (BASSSQ) and found that pre-service science teachers believe in the objectivity of scientific knowledge and yet believe that it is subject to change.

The results of the studies discussed in this chapter revealed that students and teachers did not possess adequate conceptions of nature of science. The underlying idea in all of these studies is that students' views on nature of science can be influenced, at least in part, by what is taught in the classrooms. This idea gives higher importance to the teachers' views on the same subject. Therefore, in this study, the views of preservice science teachers on nature of science issues were investigated to have detailed information about their views and to make room for the future studies to fill their missing points if exist on this issue.

Irrespective of the assessment instruments used, studies repeatedly indicated that elementary and secondary science teachers' views were not consistent with contemporary conceptions of NOS (e.g., Abd-El-Khalick & BouJaoude, 1997; Aguirere, Haggerty, & Linder, 1990; Pomeroy, 1993). In some cases, teachers' scores on those assessment instruments were not different from or lower than their students' scores (e.g., Miller, 1963). Science teachers held naive views of several important aspects of NOS. A significant proportion of teachers, for example, did not endorse the tentative nature of scientific knowledge. Rather, they believed that science is a body of knowledge that has been "proven" to be correct (Augirere et al., 1990). Many teachers held naive views of the meaning and function of scientific theories and laws and/or ascribed to a hierarchical view of the relationship between the two, whereby theories become laws with the accumulation supporting evidence (Abd-El-Khalick &BouJaoude, 1997). A majority of teachers still held a positivistic, idealistic view of science (Pomeroy, 1993); others believed in a universal stepwise procedure, "The Scientific Method," for "doing science," thus dismissing the creative and imaginative nature of the scientific endeavor (Abd-El-Khalick &BouJaoude, 1997; Lederman, 1992). In an attempt to mitigate this state of affairs, research efforts were directed toward enhancing science teachers' conceptions of NOS (Akerson, Abd-El-Khalick & Lederman, 2000).

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2.5. Relationships among teachers' conceptions of NOS, classroom practices and students' conceptions of NOS

Lederman (1992) stated that prior research had focused on student and teacher characteristics or curriculum development to the exclusion of any direct focus on actual classroom practice and/or teacher behaviors. Although research designed to assess students' and teachers' conceptions continues to the present day there is clearly less willingness to accept the assumptions that guided earlier research, and the focus is upon the realities of daily classroom instruction.

Yager (1966) selected eight experienced teachers to use a given inquiry-oriented curriculum. All of them utilized the same number of days of discussion, laboratories, examinations, and instructional materials. At the end, it was concluded that there were significant differences in students' ability to understand the nature of science when they were taught by different teachers (cited in Lederman, 1992).

Yager and Pennick (1984) studied on that, whether students have attitudes, perceptions, and feelings in and about science classes. A total of 2500 students from aged 13 and 17 participated the study-the third assessment in science by the Natural Assessment of Educational Progress (NAEP)- were selected randomly from the US.

Some of the results of this study listed the followings: students perceived that as 13-years-olds they have more opportunity than 17 years-olds to choose the way they want to learn science, select the order they wish to learn the topic, work at their own pace, and decide when assignments or tests are to be done. Thirteen-year-olds were even more optimistic about the ultimate utility of the science knowledge they were gaining.

Lederman (1986) investigated some classroom variables (i.e., teacher behaviors and classroom climate) which are related to changes in high school students' conceptions of the nature of science. The subject for the study consisted of 18 senior high school biology teachers and the students from one randomly selected tenth grade biology class of each teacher. A total of 409 students constituted the student sample. The study was performed in three steps; Nature of Scientific Knowledge Scale (NSKS) Pre-test, classroom observations, NSKS post-test. The ability of the qualitatively derived classroom variables to statistically discriminate between "high" and "low" teachers/classes was assessed. The teachers/classes of the "high" group were typically more pleasant and supportive than those of the "low" group. Teachers in the high group tended to ask questions more frequently. The questions tended to be of a higher cognitive level and problem solving in nature.

Lederman and Zeidler (1987) performed a study to test the validity of the prevalent assumption that a teacher's conception of the nature of science directly influences his/her classroom behavior. The subject of the study consisted of 18 senior-high school biology teachers and one randomly selected tenth grade biology class of each teacher. The NSKS was administered to the teachers as pre- and post-test. They conducted intensive qualitative observations in each of the 18 classrooms following the NSKS pretest but prior to the posttest. However, the data of this investigation did not support the prevalent assumption that teacher's classroom behavior is directly influenced by his/her conception of the nature of science.

Using purposive sampling and qualitative case study approach, Brickhouse (1989) investigated three secondary science teachers' views on the relationship between science and technology, and the influence of such views on classroom practice and the relationship between the same teachers' conceptions of the nature of science and classroom practice. Over a 4-month period, at least 4 hours of interviews and 35 hours of classroom observations were amassed for each of the teachers. Additional data were collected in the forms of tests, quizzes, and instructional materials. Two of the three teachers (who were also experienced) exhibited classroom practices that were consistent with their personal views and philosophy, whereas the beginning teacher's classroom practices were not congruent with his beliefs.

In a comprehensive study involving both qualitative and quantitative techniques, Duschl and Wright (1989) observed and interviewed 13 science teachers in a large urban high school. Their results convincingly indicated that the nature and role of scientific theories are not integral components in the constellation of influences affecting teachers' educational decisions. The nature of science was not being considered or thought to students as a consequence of perceived students' needs, curriculum guide objectives, and accountability.

Gallagher (1991) reported the results of a series of investigations related to preservice and inservice secondary science teachers' knowledge and beliefs about the philosophy of science, and how these beliefs and knowledge affect classroom practice. Given the dominant role played by textbooks, an initial analysis of science textbooks provided some data on how science is presented to secondary students. In general it was concluded that textbooks give little attention to the history of science and the application of science to students' daily lives. Following the analysis of textbooks, over a period of two years, 27 secondary science teachers from five schools were investigated in an ethnographic study. Data was gathered from the observation over 1000 science classes and numerous formal and informal interviews/conversations with the teachers. Twenty-five of the teachers were shown to possess "unsettling" views of the nature of science, and their actual lessons devoted virtually no time discussions related to the nature of science.

Abd-El-Khalick, Bell, and Lederman (1998) studied to delineate the factors that mediate the translation of preservice teachers' conceptions of the nature of science into instructional planning and classroom practice. Fourteen preservice secondary science teachers participated in the study. Prior to their student teaching, participants responded to an open-ended questionnaire designed to assess their conceptions of the nature of science (NOS). Observation notes were collected. Following students teaching, participants were individually interviewed to validate their responses to the open-ended questionnaire and to identify the factors or constraints that mediate the translation of their conceptions of the NOS into their classroom teaching. Participants were found to possess adequate understandings of several aspects of the NOS including the empirical and tentative nature of science, the distinction between observation and inference, and the role of subjectivity and creativity in science. Many claimed to have taught the NOS through science-based activities. However data analysis revealed that explicit references to the NOS were rare in their planning and instruction.

Similarly, the study performed by Lederman (1999) investigated the relationship of teachers' understanding of the nature of science and classroom practice and to delineate factors that facilitate or impede a relationship. Five high school biology teachers, ranging in experience from 2 to 15 years, comprised the sample for this investigation. During one full academic year, multiple data sources were collected and included classroom observations, open-ended questionnaires, semistructured and structured interviews, and instructional plans and materials. In addition, students in each of the teachers' conceptions of science do not necessarily influence classroom practice. Of critical importance were teachers' level of experience, intentions, and perceptions of students.

Lederman et al., (1998) concluded that research on the nature of science over the last three decades has provided at least four consistent findings, regardless of the instruments used in the investigations: science teachers appear to have inadequate conceptions of the nature of science; efforts to improve teachers' conceptions of the nature of science have achieved some success when either historical aspects of scientific knowledge or direct attention to the nature of science have been included; academic background variables have not been significantly related to teachers' conceptions of the nature of science; the relationship between teachers' conceptions of the nature of science and classroom practice is not clear, and the relationship is mediated by a large array of instructional and situational concerns.

The results of the studies discussed in this chapter revealed that students and teachers did not possess adequate conceptions of nature of science. The underlying idea in all of these studies is that students' views on nature of science can be influenced, at least in part, by what is taught in the classrooms. This idea gives higher importance to the teachers' views on the same subject. Therefore, in this study, the views of preservice science teachers on nature of science were investigated to have detailed information about their views and to make room for the future studies to fill their missing points if exist on nature of science.

CHAPTER 3

METHOD

In this chapter, the main problem, the research question, information about the subjects of the study, the data collection procedure, and the data analysis procedure to conduct this study were presented.

3.1. Main Problem

The purpose of this study was to investigate the views of Turkish preservice science teachers' on nature of science concepts.

3.2. Research Question

What kind of views do the preservice science teachers possess on the nature of science concepts?

3.3. Population and Sample Selection

All preservice science teachers in Turkey were identified as the target population of this study. However it is appropriate to define an accessible population since it is not easy to come into contact with this target population. The accessible population was determined as "all preservice science teachers in Ankara". This is the population for which the results of this study will be generalized. Since Ankara is a cosmopolitan city of Turkey, it was assumed that it would accommodate many different groups of people. Therefore, the sample is considered to bear sufficient heterogeneity in terms of the preservice science teacher profile in Turkey.

There are three universities that had the department of elementary education in this city. These were Gazi University, Middle East Technical University (METU) and Hacettepe University. These universities thought as the sample of this study.

The present study included a qualitative and a quantitative part and both were conducted with preservice science teachers from three universities in Ankara, Turkey. In quantitative part of this study, a total of 166 preservice science teachers (99 females and 67 males) were enrolled (Table 3.1). When the source of preservice science teachers graduated lycees were considered, 86 of them was observed to be graduated from a general lycees, 29 of them from teachers lycees, 3 of them from Anatolian lycees, 3 of them from vocational lycees and 45 of them from other lycess. According to the information obtained from the guide book of the University Entrance Examination of year 2000, the total number of preservice science teachers from these three universities is about 390. The capacity of these three universities holds as the base for the number. The total number of the participants of the study includes almost 43 % of accessible population.

In qualitative part of this study, nine preservice science teachers, three female and six male, were interviewed to obtain information about their views on nature of science concepts. They were selected from only one university by convenient sampling. They were interviewed by using a semi-structured interview procedure.

Table 3.1. Distributions of sample by university and gender.

Universities	Gender				Total	
	Female		Male			
	Frequency	%	Frequency	%	Frequency	%
Gazi University	68	55.3	55	44.7	123	100
Hacettepe University	17	63	10	37	27	100
Middle East Technical University	14	87.5	2	12.5	16	100
Total	**99**	**59.6**	**67**	**40.4**	**166**	**100**

3.4. Data Collection Instruments

In the present study, twenty-one selected items from Views on Science-Technology-Society (VOSTS) item pool were used in order to assess preservice science teachers' views on nature of science. Besides the VOSTS, interviews were conducted with 9 senior preservice science teachers from METU about the nature of science concepts voluntarily by the researcher.

3.4.1. Turkish Version of Views on Science-Technology-Society (T-VOSTS)

The instrument of the study is Turkish version of Views on Science-Technology-Society (T-VOSTS), which contain twenty-one selected and adapted items from VOSTS item pool. The VOSTS (Aikenhead, Ryan & Fleming, 1989) is an inventory of 114 empirically developed multiple-choice items assessing views on nine categories. These categories are: Science and Technology, Influence of Society on Science/Technology, Future Category, Influence of Science/Technology on Society, Influence of School Science, Characteristics of Scientists, Social Construction of Scientific Knowledge, Social Construction of Technology and Nature of Scientific Knowledge. The VOSTS was developed in a six-year period of time. The multiple choices were developed from written responses and from interviews with Canadian high school students. Aikenhead and Ryan (1992) stated that this is the major difference between the VOSTS and many other instruments, which typically are composed by researcher working under the erroneous assumption that respondents will perceive and interpret the language in the items in the same way as the researcher does. According to Aikenhead and Ryan (1992), it is inappropriate to speak out about the validity of empirically developed instruments, such as the VOSTS, in the traditional sense (e.g. face, content, criterion) because the validity of empirically developed instruments arises from a qualitative research paradigm. According to these researchers, empirically developed instruments seek to uncover the perspective of the respondent and reveal the legitimacy of that perspective from the respondent's point of view, not the imposed viewpoint of the researcher. As in the qualitative research, it is assumed with empirically developed instruments that the respondents understand the complex interactions being studied and account for the influence of values on the interactions better than the investigator. Further, Aikenhead and Ryan (1992) argue that the validity of an empirically developed instrument is established by the "trustworthiness" of the method used to develop the items as the validity of the process and of the final instruments lies in the trust which subsequent researchers place in the development process which has been described. Thus, it was assumed that the VOSTS items possessed an inherent validity that originated from the process used to develop them.

Similarly, the concept reliability as it applies to empirically developed instruments such as the VOSTS follows from the qualitative research paradigm, where in the dependability of the results is of major concern; that is, the validity and reliability of qualitative data depend to a great extent on the methodological skill, sensitivity, and integrity of the researcher. Rather than demanding that others get the same results, one wants to concur that, given the data collected, the results make sense that the results are dependable. In addition, Aikenhead and Ryan (1992) also argue that empirically developed items yield non-parametric data that does not fulfill the continuity and equal intervals of measures assumption that underlies parametric analysis procedures. Hence, they add traditional procedures such as Coefficient Alpha that are used to assess the reliability of instruments that yield parametric scores and are based on assumptions that are not tenable in the case of empirically developed instruments, are not appropriate for instruments such as the VOSTS. As a result, VOSTS items were assumed to be reliable and based upon agreement that the data presented Aikenhead and Ryan made sense. On the other hand, recently Botton and Brown (1998) argues that the concept of reliability was central to any research instrument and consider it an oversight that this issue did not receive the attention it deserved from the large body of research involving VOSTS. Thus, they selected 27 items from the first and ninth sections of the VOSTS and tried to determine reliability of these items by using cross-tabulation and cluster analysis procedures following a retest. This study showed that all 27 items selected were generally found to be reliable, although when put to a severe treatment, 24 of 27 items were found to be reliable.

In the present study, a preliminary set of 22 items was selected as they corresponded to the purposes of the assessment for the pilot study by the researcher with the help of two competent science educators. The items were selected from the ninth part epistemology of science (or the nature of scientific knowledge) of the VOSTS item pool. Then these selected items were translated and adapted by the researcher and two science educators. In addition to this a linguist in Academic Writing Center in METU checked selected items' translations. Then the pilot study was done using 19 third-year students of Elementary Science Education Department of METU. One reason of this pilot study was to check the quality of the translations. The other reason was this inventory was developed with and for the high school students so it would be better doing a pilot with preservice science teachers.

Aikenhead (1987), found that in 82% of the cases students could better express their views on science-technology-society topic by selecting a response from among the multiple choices provided under VOSTS items. Therefore, if less than 18 percent mark the last choice, "None of these choices fits my basic viewpoint," then there will be no need for modifying the items, because it can be considered to be an indicator that the VOSTS items would be appropriate for that sample. The pilot study also showed that the time given to answer the questions was enough for the participants. In this study, according to pilot study, for two items respondents selected the last choice and these questions were omitted for the actual administration. In addition to this, after pilot study one item selected from the first part about the definition and meaning of science. Because respondents' views about the definition of science were important for this study. Finally, Turkish version of VOSTS (T-VOSTS) was constructed with 21 items (Table 3.2) after necessary changes upon the pilot study.

Table 3.2. Subscales of the items used in the Turkish version of VOSTS.

Item Number	Items' root	Subscales
1	Defining science is difficult because science is complex and does many things. But MAINLY science is:	Defining science
2	Scientific observations made by competent scientists will usually be different if the scientists believe different theories.	Nature of observations
3	Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.	Nature of scientific models
4	When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.	Nature of classification schemes
5	Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.	Tentativeness of scientific knowledge
6	Scientific ideas develop from hypotheses to theories, and finally, if they are good enough to being scientific laws.	Hypotheses, theories & laws
7	When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions *must be true* in order for science to progress properly.	
8	Good scientific theories explain observations well. But good theories are also *simple* rather than complex.	
9	When scientists investigate, it is said that they follow the scientific method. The scientific method is:	Scientific approach to investigations
10	The best scientists are those who follow the steps of the scientific method.	
11	Scientific discoveries occur as a result of series of investigations, each one building on an earlier one, and each one leading logically to the next one, until the discovery is made.	
12	Scientists publish the result of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way.	

Table 3.2. (Continued)

13	Scientists should NOT make errors in their work because these errors slow the advance of science.	Scientific approach to investigations
14	Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what p*robably* might happen. They cannot tell what will happen for certain.	Precision & uncertainty in scientific/ technological knowledge
15	If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer.	Logical reasoning
16	Science rests on the assumption that the natural world can *not b*e altered by a supernatural being (for example, a deity).	Fundamental assumptions for all science
17	For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists d*iscover* scientific LAWS. Others think that scientists invent them. What do you think?	Epistemological status of scientific knowledge
18	For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists d*iscover* scientific HYPOTHESES. Others think that scientists invent them. What do you think?	
19	For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists d*iscover* scientific THEORIES. Others think that scientists invent them. What do you think?	
20	Scientists in different fields look at the same thing from very different points of view (for example, H^+ causes chemists to think of acidity and physicists to think of protons). This makes it difficult for scientists in different fields to understand each others' work.	Paradigms versus coherence of concepts across disciplines
21	Scientists in different fields look at the same thing from very different points of view (for example, H^+ causes chemists to think of acidity and physicists to think of protons). This means that one scientific idea has different meanings, depending on the field scientist works in.	

3.4.2. Interview with Preservice Science Teachers

The interviews served as the important source of data and addressed the preservice science teachers' views concerning the nature of science. During the interviews, a semi-structured interview (see Appendix B) schedule was used by the researcher. The schedule was left flexible to allow to students to express themselves in relative freedom and to enable the interviewer to ask thought-provoking questions. The confidentiality of the data collection process, and participants' rights were explained before the administration of the questionnaire. Participants were informed that their participation were voluntarily and confidential. Nine individuals' interviews were held each lasted approximately 30 minutes duration. All of the interviews were audiotaped and transcribed. Transcriptions were produced verbatim to provide full representation of the students' responses. Each student who agreed to participate in the study interviewed individually.

In this study, the interview questions were adapted and developed considering some instruments related with views of nature of science, such as Views of Nature of Science (VNOS form-A, VNOS form-B and VNOS form-C) (Abd-El-Khalick, 1998; Abd-El-Khalick, Bell and Lederman, 1998; Bell, 1999; cited in Lederman, Abd-El-Khalick, Bell and Schwartz, 2002). These forms of the Views of Nature of Science aimed to assess the views of the tentative, empirical, inferential, creative, and theory-laden nature of science, and the functions of and relationship between theories and laws and also the views of the social and cultural embeddedness of science and the existence of a universal scientific method.

Interviewed questions covered eight main issues of the NOS. During the interviews, the items related with these eight issues, item numbers and the aims of these each items were as the followings;

1. How do students define science and interpret the differences of science from other disciplines (such as religion, philosophy)?

Item 1 aims to assess respondents' views regarding science as a discipline to address questions about the natural world, the role of science in providing explanations for natural phenomena, and the role that empirical evidence plays in science that separates science from other "ways of knowing."

2. How do students define experiment and scientific method, and also state the importance of experiment in the development of a scientific knowledge?

Item 2 and 3 are used in combination to assess respondents' views of investigative processes in science and also elicits responses regarding existence of multiple investigation (such as experimentation involving controlled variables, correlational studies, and descriptive investigations) that do not all follow the traditional "scientific method" or a set of established logical steps requiring a testable hypothesis.

3. How do students' interpret the nature of scientific models and classifications in terms of being copies of reality?

Item 4 refers respondents to assess their understandings of the role of human inference and creativity in developing scientific explanations, classifications, and models based on available data, and the notion the scientific models and classifications are not copies of reality.

4. How do students state the differences between scientific theories and laws?

Item 5 aims to assess respondents' views of the development of and relationship between scientific theories and laws. In addition to this respondents may express many ideas related to their understandings of the nature of science and science process as they attempt to delineate the differences between theories and laws.

5. Do the students believe that a scientific theory ever changes?

Item 6 and 10 assess respondents' understanding of the tentative nature of scientific theories and reasons why science is tentative. In addition to these respondents may often indicate views of the role of subjectivity, creativity, inference, and the socio-cultural embeddedness of the scientific endeavor, as well as the interdependent nature of these aspects.

6. How do students interpret the scientists' different hypotheses and theories using the same set of data?

Item 7 assesses respondents' understandings of reasons for controversy in science when scientists use the same available data. Ideas of subjectivity, inference, creativity, social and cultural influences, and tentativeness may be elicited. This question also aims to assess respondents' beliefs about what influences data interpretation including personal preferences and bias (personal subjectivity) to differing theoretical commitments and impacts of social and cultural values.

7. Do the students believe science is affected with the social and cultural values or do they believe science is universal and not affected from the by social, political, and philosophical valued of culture?

Item 8 assesses respondents' views of the impact of social and cultural values and expectations on the scientific endeavor. Additionally, views of connections between socio-cultural influences on science and subjectivity, creativity, inference, and tentativeness are often elicited.

8. How do students see the relationships among concepts, theories, and laws of biology, physics and chemistry?

Item 9 assesses respondents' views on unified characteristics of science.

The following excerpt from the interviews is an example to show how thought-provoking questions help to diagnose preservice science teachers' views.

Table 3.3. An excerpt from the interviews.

Researcher: After scientists have developed a scientific theory (e.g. atomic theory, evolution theory), does the theory ever change?

Preservice science teacher: They change, they can change…For example atomic theory has changed through the time. At first there were different theories. Now Bohr atomic theory is used. They may also change in the future.

Researcher: If you believe that scientific theories do change why we bother to learn scientific theories. Defend your answer with examples.

Preservice science teacher: We try to reach the most correct answers. The more developments in technology, the more changes in science. Our aim is to reach the best results.

3.5. Data Collection Procedure

For the collection of data from the preservice science teachers, permission was taken from the instructors that offer several courses to them in three different universities in Ankara. In the spring term of 2002-2003 academic years, data were collected by using Turkish version of VOSTS. The data were collected form preservice science teachers of Gazi University and Middle East Technical University during the class hours by the researcher herself. On the other hand, data were collected from Hacettepe University again during the class hours but by their research assistants.

For the qualitative part, nine preservice science teachers from Middle East Technical University interviewed during May 2003. They were chosen according to their willingness to participate such kind of study. Face-to-face interviews were performed during out of the school time. There was not a time limitation for the completion of the interviews. For this reason, they took different lengths of time depending on the respondents' willin gness to demonstrate their thoughts.

3.6. Methods Used to Analysis of Data

In this study, descriptive analyses were performed for data of Turkish version of VOSTS. Frequency and percentage distribution of each alternative under each one of the items were calculated and they were analyzed. For the interview part, the audio-taped interviews were transcribed and analyzed. In order to produce verbatim transcriptions of the interviewees' responses, the cassettes were replayed to check whether any missing point was present in the text. After the transcriptions were completed, the responses were categorized for each question according to the covered points of the issue in interview part to analyze them.

3.7. Assumptions and Limitations

During this study, assumptions and limitations encountered are given as below:

3.7.1. Assumptions

1. The survey was conducted under standard conditions.
2. All preservice science teachers' responses to the survey were sincere.
3. All preservice science teachers answered interview questions seriously.

3.7.2. Limitations

1. The subjects in the interview were limited to nine preservice science teachers from the last year students at a university.
2. The subjects of the survey were limited to 166 preservice science teachers.
3. The subjects of the study were selected from only the universities in Ankara so the generalization can be applied for the preservice elementary science teachers' only from the one city.
4. The nature of the instrument is not appropriate for inferential statistics since it evolved from the qualitative research paradigm.
5. Translated instruments may have the defects that are indispensable.
6. Completion time of the instrument T-VOSTS, which took about forty-five minutes and this, may have caused boredom and tiredness for some participants.
7. Because of some outside factors administration of the instrument could not be held constant, this might have affected the results of the study.

CHAPTER 4

RESULTS AND CONCLUSION

This chapter is divided into three parts. The first part deals with the descriptive analysis of VOSTS items. The second part presents the information obtained from the interviews with the preservice science teachers concerning the nature of science. The third part reveals the misconceptions of preservice science teachers on nature of science.

4.1. Descriptive Analyses of T-VOSTS Items

In this part, preservice science teachers' views about nature of science were investigated descriptively. Each of the items was consisted of a stem and different number of alternatives, which reflected some kind of views changing from realistic to naive. Bradford, Rubba and Harkness (1995) established a three-category scoring scheme according to the following definitions: Realistic (R) – the choices expresses an appropriate view on nature of science relative to the item stem; Has merit (HM) – while not realistic, the choices expresses a number of legitimate points about nature of science relative to the item stem; Naive (N) – the choices expresses a view about nature of science, relative to the item stem, that is inappropriate or not legitimate. In this categorization, realistic views supported by post-positivists and naive views supported by logical positivists.

The items are examined respondents' views on different topics about nature of science. These topics and item numbers are:

<u>Definitions of Science</u>

1. Defining science (e.g., instrumentalism, curiosity satisfaction, social enterprise). (Item1)

Nature of Scientific Knowledge

1. Nature of observations (e.g., theory ladenness, perception bound). (Item 2)
2. Nature of scientific models. (Item 3)
3. Nature of classification schemes. (Item 4)
4. Tentativeness of scientific knowledge. (Item 5)
5. Hypotheses, theories and laws (e.g., definition, role of assumptions, criteria for belief). (Items 6, 7, 8)
6. Scientific approach to investigations (e.g., nonlinearity, rejection of a stepwise procedure, "the scientific method" as a writing style). (Items 9, 10, 11, 12, 13)
7. Precision and uncertainty in scientific/technological knowledge (e.g., probabilistic reasoning). (Item 14)
8. Logical reasoning (e.g., cause/effect problems, epidemiology and etiology). (Item 15)
9. Fundamental assumptions for all science (e.g., uniformitarianism). (Item 16)
10. Epistemological status of scientific knowledge (ontology as an assumption, questioning logical positivism). (Items 17, 18, 19)
11. Paradigms versus coherence of concepts across disciplines. (Items 20, 21)

The items asked according to the topics given above were answered by the participants and the following results were obtained. Individual Turkish version of VOST items' results are summarized in Tables 4.1 -4.21. Each table presented the following information on one of the VOSTS items: (1) the item statement; (2) The item's multiple choice categorized by the Realistic/Has Merit/Naive scheme; and (3) the multiple-choice response percentage data for each sample.

Defining Science (Item 1)

The first item investigated preservice science teachers' views on defining science. Preservice science teachers' images of science will certainly color their views on its epistemology. For example, epistemology will differ greatly between preservice science teachers who see science as an encyclopedia of facts about the world and those who see science as a facet of Western culture. Therefore, when interpreting preservice science teachers' responses to questions on the epistemology of science, it will be helpful to know what students think science is (Ryan & Aikenhead, 1992).

When participants were asked about definition of science, their responses varied. Science was seen by preservice science teachers as: a body of knowledge (24,7%, alternative B), exploring the unknown (31,3%, alternative C), improving the world (31,3%, alternatives E and F), a social institution (4,8%, alternative G), and indefinable (1,8%, alternative H). Preservice science teachers had not acquired uniform view of science.

Preservice science teachers selecting E and F alternatives, which were constituted 31,3 % of the whole sample, confused the science and technology with each other. Science teachers who selected alternative A (1,2%) regarded science as a field of biology, chemistry, and physics. The most contemporary view about science (alternative G) which gives social aspects of science was selected only 4,8 %. Thus, while preservice science teachers believed that science is mainly content or process, they also viewed science as an instrument of social purpose-an ‘instrumentalist” perspective, confused it with technology (Table 4.1).

Table 4.1. Percentage of preservice science teachers' responses to item 1.

Defining science is difficult because science is complex and does many things. But MAINLY science is:		
%		***Your Position, Basically:***
1,2	**A.**	**a study of fields such as biology, chemistry and physics.**
24,7	**B.**	**a body of knowledge, such as principles, laws and theories, which explain the world around us (matter, energy and life).**
31,3	**C.**	**exploring the unknown and discovering new things about our world and universe and how they work.**
0	**D.**	**carrying out experiments to solve problems of interest about the world around us.**
0	**E.**	**inventing or designing things (for example, artificial hearts, computer, space vehicles).**
31,3	**F.**	**finding and using knowledge to make this world a better place to live in (for example, curing diseases, solving pollution and improving agriculture).**
4,8	**G.**	**an organization of people (called scientists) who have ideas and techniques for discovering new knowledge.**
1,8	**H.**	**No one can define science.**

Naive: 59% **Has Merit: 31,3%** **Realistic: 4,8%**

Nature of Observations (Item 2)

The second item was asked in order to reveal whether preservice science teachers believed 100% alikeness in scientific observations or not. According to the responses of participants, 30,9 (alternative C), 6,1 (alternative D) and 1,8 (alternative E) percentages believed that observations of different scientists would be almost identical even when scientists based their questions on different theories, which is a inconsistent view with contemporary view (Table 4.2). On the other hand, alternative A (19,4%) and alternative B (37 %) selected by preservice science teachers were parallel with these contemporary views that scientific observations made by competent scientists will usually be different if the scientists believe different theories. Briefly, generally preservice science teachers held consistent views on that item.

Table 4.2. Percentage of preservice science teachers' responses to item 2.

Scientific observations made by competent scientists will usually be different if the scientists believe different theories.		
%		***Your Position, Basically:***
19,4	**A.**	**Yes, because scientists will experiment in different ways and will notice different things.**
37,0	**B.**	**Yes, because scientists will think differently and this alter their observations.**
30,9	**C.**	**Scientific observations will not differ very much even though scientists believe different theories. If the scientists are indeed competent their observations will be similar.**
6,1	**D.**	**No, because, observations are as exact ax possible. This is how science has been able to advance.**
1,8	**E.**	**No, observations are exactly what we see and nothing more; they are the facts.**

Naive: 38,8% **Realistic: 56,4%**

<u>Nature of Scientific Models (Item3)</u>

Scientific models are based on socially constructed scientific facts. Do preservice science teachers see models as duplicates of reality or as human inventions? As shown in Table 4.3, preservice science teachers take essentially three positions: 1) models are copies of reality (47,2 %, alternatives A, B and C); 2) models come close to being copies of reality (21,8%, alternative D); and 3) models are not copies of reality (30,9%, alternatives E, F and G). Thus, approximately half of the preservice science teachers (47,2%, alternatives A, B and C) held a "naive realist" view (Nadeau and Desautels, 1984) contrary to contemporary epistemology of science. About 22 % of preservice science teachers (alternative D) do not appear to embrace a purely epistemological viewpoint. Vestiges of ontological thinking (naive realism) remain.

Table 4.3. Percentage of preservice science teachers' responses to item 3.

Many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality.		
%		***Your Position, Basically:***
		Scientific models are copies of reality:
1,2	**A.**	**because scientists say they are true, so they must be true.**
13,3	**B.**	**because much scientific evidence has proven them true.**
32,7	**C.**	**because they are true to life. Their purpose is to show us reality or teach us something about it.**
21,8	**D.**	**Scientific models come close to being copies of reality, because they are based on scientific observations and research.**
		Scientific models are not copies of reality:
15,8	**E.**	**because they are simply helpful for learning and explaining, within their limitations.**
12,1	**F.**	**because they change with time and with the state of our knowledge, like theories do.**
3,0	**G.**	**because these models must be ideas or educational guesses, since you can't actually see the real thing.**

Naive: 69% **Has Merit: 15,1%** **Realistic: 15,8%**

<u>Nature of Classification Schemes (Item 4)</u>

When preservice science teachers addressed the topic of classification schemes, there was a shift away from the “naive realism” viewpoint (duplication of reality). In response to item 4, only 16,8% of preservice science teachers believed classification schemes matched the way nature really is, whereas fully 66,2 % (alternatives D, E and F) recognized the human inventive character of scientific classification schemes. Apparently, preservice science teachers were more familiar with the epistemology of classification schemes than they were with models. Unfortunately, more science-related public debates (such as the greenhouse effect) center on models than on classification schemes (Table 4.4).

Table 4.4. Percentage of preservice science teachers' responses to item 4.

When scientists classify something (for example, a plant according to its species, an element according to the periodic table, energy according to its source, or a star according to its size), scientists are classifying nature according to the way nature really is; any other way would simply be wrong.	
%	***Your Position, Basically:***
8,4	**A. Classifications match the way nature really is, since scientists have proven them over many years of work.**
8,4	**B. Classifications match the way nature really is, since scientists use observable characteristics when they classify.**
15,7	**C. Scientists classify nature in the most simple and logical way, but their way isn't necessarily the only way.**
30,7	**D. There are many ways to classify nature, but agreeing on one universal system allows scientists to avoid confusion in their work.**
25,9	**E. There could be other correct ways to classify nature, because science is liable to change and new discoveries may lead to different classifications.**
9,6	**F. Nobody knows the way nature really is. Scientists classify nature according to their perceptions or theories. Science is never exact, and nature is too diverse. Thus, scientists could correctly use more than one classification scheme.**

Naive: 16,8% **Has Merit: 15,7%** **Realistic: 66,2%**

Tentativeness of Scientific Knowledge (Item 5)

As evidenced by Table 4.5, virtually all the preservice science teachers in the sample agreed that scientific knowledge changes. But their reasons revealed four very different and somewhat conflicting views: (1) Old facts change and become different facts; (2) Old facts become wrong facts; (3) Old facts do not change; only their interpretation and application changes; (4) Old facts do not change; new facts are simply added to old facts.

One of the characteristics of the scientific knowledge is its tentativeness. Preservice science teachers selecting the first two alternatives A and B, (79,5 %) were considered to believe that scientific knowledge was subject to change. The respondents choosing alternative A took the falsificationist perspective and respondents choosing alternative B took the constructionist perspective. On the other hand, remaining preservice science teachers selecting alternatives C and D (18 %) believed that facts were unchangeably true, in other words, were not tentative. It might be said that the majority of the sample had contemporary views about the tentativeness of scientific knowledge.

Table 4.5. Percentage of preservice science teachers' responses to item 5.

%	Even when scientific investigations are done correctly, the knowledge that scientists discover from those investigations may change in the future.
	Your position, basically:
	Scientific knowledge changes:
42,8	**A. because new scientists disprove the theories or discoveries of old scientists. Scientists do this by using new techniques or improved instruments, by finding new factors overlooked before, or by detecting errors in the original "correct" investigations.**
36,7	**B. because the old knowledge is reinterpreted in the light of new discoveries. Scientific facts can change.**
10,2	**C. Scientific knowledge appears to change because the interpretation or the application of the old facts can change. Correctly done experiments yield unchangeable facts.**
7,8	**D. Scientific knowledge appears to change because new knowledge is added on to old knowledge, the old knowledge doesn't change.**

Naive: 18% **Realistic: 79,5%**

Hypotheses, Theories and Laws (Item 6, 7 and 8)

Do preservice science teachers view hypotheses, theories, and laws as different types of statements? As it may be seen in Table 4.6, only 1,2% of the preservice science teachers held such a view (alternative E). The majority (92,2%) expressed a simplistic hierarchical relationship in which hypotheses become theories and theories become laws, depending on the amount of "proof behind the idea." Preservice science teachers appear to be ignorant of the fact that many laws in science were known before any theories were developed to explain them. Boyle's Law is a case in point.

Although the terms hypothesis, theory and law have been variously defined, the following definitions tend to be widely accepted (Klopfer, 1966). Theories are explanations (often mechanistic and associated with visual representations called models) in which scientists place a high degree of confidence.

Laws are general descriptions that enjoy a high degree of scientific confidence (often associated with classification schemes). Hypotheses are very tentative explanations or descriptions that guide investigations. In other words, theories and laws are different types of statements, and both are distinguished from hypotheses by virtue of the degree to which they have been accepted by the scientific community.

Table 4.6. Percentage of preservice science teachers' responses to item 6.

%	Scientific ideas develop from hypotheses to theories, and finally, if they are good enough to being scientific laws. *Your Position, Basically:*
	Hypotheses can lead to theories which can lead to laws:
50,3	**A. because a hypothesis is tested by experiments, if it proves correct, it becomes a theory. After a theory has been proven true many times by different people and has been around for a long time, it becomes a law.**
35,2	**B. because a hypothesis is tested by experiments if there is supporting evidence, it is a theory. After a theory has been tested many times and seems to be essentially correct, it's good enough to become a law.**
6,7	**C. because it is logical way for scientific ideas to develop.**
2,4	**D. Theories can't become laws because they both are different types of ideas. Theories are based on scientific ideas which are less than %100 certain, and so theories can't be proven true. Laws, however, are based on facts only and are %100 sure.**
1,2	**E. Theories can't become laws because they both are different types of ideas. Laws describe things in general. Theories explain these laws. However, with supporting evidence, hypotheses may become theories (explanations) or laws (descriptions).**

Naive: 94,6% **Realistic: 1,2%**

Item 7 was about the views of preservice science teachers on the scientific assumptions. It indicated that when developing new theories or laws, scientists needed to make certain assumptions about nature. The item questioned whether these assumptions must be true or not in order for science to progress properly. To that item, 30,7 % (alternative E) of the participants gave the realistic answer, which stated that scientists must make some true or false assumptions in order to start an investigation (Table 4.7). Other preservice science teachers (about 62,6 % of the whole sample) selected A, B, C, D and F alternatives, which were inconsistent with the contemporary views.

Table 4.7. Percentage of preservice science teachers' responses to item 7.

When developing new theories or laws, scientists need to make certain assumptions about nature (for example, matter is made up of atoms). These assumptions *must* be *true* in order for science to progress properly.		
%		***Your Position, Basically:***
		Assumptions MUST be true in order for science to progress:
14,5	**A.**	**because correct assumptions are need for correct theories and laws. Otherwise scientists would waste a lot of time and effort using wrong theories and laws.**
4,2	**B.**	**otherwise society would have serious problems, such as inadequate technology and dangerous chemicals.**
12,0	**C.**	**because scientists do research to prove their assumptions true before going on with their work.**
30,7	**D.**	**It depends. Sometimes science needs true assumptions in order to progress. But sometimes history has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.**
30,7	**E.**	**It doesn't matter. Scientists have to make assumptions, true or not, in order to get started on a project. History has shown that great discoveries have been made by disproving a theory and learning from its false assumptions.**
1,2	**F.**	**Scientists do not make assumptions. They research an idea to find out if the idea is true. They don't assume it is true.**

Naive: 62,6% **Realistic: 30,7%**

The last item (Table 4.8) revealed preservice science teachers' views on simplicity (or complexity) of language used in science and to question their views on the nature of theories. About 71% of the preservice science teachers (alternatives A, B, and D) held realistic views about this topic and they took part in the favor of simplicity of scientific knowledge. On the other hand, the most realistic answer (alternative A) to that item was selected about 15% of the whole sample. Only about 20% (selecting alternatives C, E, and F) of whole preservice science teachers believed that complexity was the prerequisite for the quality of a theory.

Table 4.8. Percentage of preservice science teachers' responses to item 8.

Good scientific theories explain observations well. But good theories are also *simple* rather than complex.		
%		***Your Position, Basically:***
14,5	**A.**	**Good theories are simple. The best language to use in science is simple, short, direct language.**
22,3	**B.**	**It depends on how deeply you want to get into the explanation. A good theory can explain something either in a simple way or in a complex way.**
15,1	**C.**	**It depends on the theory. Some good theories are simple, some are complex.**
33,7	**D.**	**Good theories can be complex, but they must be able to translate into simple language if they are going to be used.**
3,0	**E.**	**Theories are usually complex. Some things cannot be simplified if a lot of details are involved.**
1,8	**F.**	**Most good theories are complex. If the world was simpler, theories could be simpler.**

Naive: 19,9% **Has Merit: 56%** **Realistic: 14,5%**

Scientific Approach to Investigations (Item 9, 10, 11, 12 and 13)

What are preservice science teachers' views on 'the scientific method'? When they were asked to choose a description (Table 4.9), the largest group (44,5%) selected position that read: "questioning, hypothesizing, collecting data and concluding." The next largest group (12,2%) chose the position that described the scientific method as: "getting facts, theories or hypotheses efficiently." The remaining respondents spread their choices over the other eight positions. Unfortunately none of the preservice science teachers chose the option which stated that "there really is no such thing as the scientific method" even though this position represents the most contemporary view (alternative J).

Table 4.9. Percentage of preservice science teachers' responses to item 9.

When scientists investigate, it is said that they follow the scientific method. The scientific method is:

%		***Your Position, Basically:***
4,9	**A.**	**the lab procedures or techniques; often written in a book or journal, and usually by a scientist.**
0,6	**B.**	**recording your results carefully.**
11,6	**C.**	**controlling experimental variables carefully, leaving no room for interpretation.**
12,2	**D.**	**getting facts, theories or hypotheses efficiently.**
9,8	**E.**	**testing and retesting- proving something true or false in a valid way.**
1,2	**F.**	**postulating theory then creating an experiment to prove it.**
44,5	**G.**	**questioning, hypothesizing, collecting data and concluding.**
6,7	**H.**	**a logical and widely accepted approach to problem solving.**
2,4	**I.**	**an attitude that guides scientists in their work.**
0	**J.**	**Considering what scientists actually do, there is no such thing as the scientific method.**

Naive: 47% **Has Merit: 46,9%** **Realistic: 0%**

When preservice science teachers were asked whether the best scientists "follow the steps of the scientific method" (Table 4.10), they tended to favor those positions which suggest that there is a definite pattern to doing science (76,3%, alternatives A-C). In addition to this, about 42% of the whole sample selected alternative C in which creativity, imagination and originality had important places in carrying out scientific investigations. According to results, 7,3% of the preservice science teachers selected (alternative E) that many scientific discoveries were made by accident, a view supported by media. Few students (8,5%) chose D, the contemporary view of most epistemologists- that scientists "use any method that might get favorable results." The idea of using any method corresponds in most participants' minds to the idea that there is no such thing as the scientific method.

Table 4.10. Percentage of preservice science teachers' responses to item 10.

The best scientists are those who follow the steps of the scientific method.		
%		***Your Position, Basically:***
30,5	**A.**	**The scientific method ensures valid, clear, logical, and accurate results. Thus, most scientists will follow the steps of the scientific method.**
3,7	**B.**	**The scientific method should work well for most scientists; based on what we learned in school.**
42,1	**C.**	**The scientific method is useful in many instances, but it does not ensure results. Thus, the best scientists will also use originality and creativity.**
8,5	**D.**	**The best scientists are those who use any method that might get favorable results (including the method of imagination and creativity).**
7,3	**E.**	**Many scientific discoveries were made by accident, and not by sticking to the scientific method.**

Naive: 41,5% **Has Merit: 42,1%** **Realistic: 8,5%**

Item 11 investigated whether preservice science teachers believed scientific discoveries result from a logical series of investigations or not. According to responses of preservice science teachers about 54% (alternatives A and B) believed that scientific discoveries result from a logical series of investigation, which is a view consistent with contemporary views (Table 4.11). On the other hand, about 28% of the all respondents believed that scientific discoveries do not occur as a result of series investigations.

Table 4.11. Percentage of preservice science teachers' responses to item 11.

Scientific discoveries occur as a result of series of investigations, each one building on an earlier one, and each one leading logically to the next one, until the discovery is made.		
%		***Your Position, Basically:***
		Scientific discoveries result from a logical series of investigations:
33,9	**A.**	**because experiments (for example, the experiments that led to the model of the atom, or discoveries about cancer) are like laying bricks onto a wall.**
20,0	**B.**	**because research begins by checking the results of an earlier experiment to see if it is true. A new experiment will be checked by the people who come afterwards.**
16,4	**C.**	**Usually scientific discoveries result from a logical series of investigations. But science is not completely logical. There is an element of trial and error, hit and miss, in the process.**
23,0	**D.**	**Some scientific discoveries are accidental, or they are the unpredicted product of the actual intention of the scientists. However, more discoveries result from a series of investigations building logically one upon the other.**
3,0	**E.**	**Most scientific discoveries are accidental, or they are unpredicted product of the actual intention of the scientist. Some discoveries result from a series of investigations building logically one upon the other.**
		Scientific discoveries do not occur as a result of a logical series of investigations:
0,6	**F.**	**because discoveries often result from the piecing together of previously unrelated bits of information.**
1,2	**G.**	**because discoveries often occur as a result of a wide variety of studies which originally had nothing to do with each other, but which turned out to relate to each other in unpredictable ways.**

Naive: 27,8% **Has Merit: 16,4%** **Realistic: 53,9%**

Item 12 was about the scientists' way while writing articles. It indicated that when scientists write an article, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way. The item questioned whether these assumptions must be true or not. To that item, about 59% (alternatives A and B) of the preservice science teachers gave the realistic answer. On the other hand, about 23% of the all respondents selected alternatives D, E, F, and G which were inconsistent with the contemporary views (Table 4.12). Alternative C selected by only 8,5% of the preservice science teachers was very close to contemporary views but still sitting on the fence.

Table 4.12. Percentage of preservice science teachers' responses to item 12.

%		Scientists publish the result of their work in scientific journals. When scientists write an article for a journal, they organize their report in a very logical orderly way. However, scientists actually do the work in a much less logical way.
%		***Your Position, Basically:***
		Articles are written in a more logical way than the actual work:
41,2	**A.**	**because scientists can think and work without following a set plan. Consequently, if you read the actual order of their thoughts and procedures, it would be confusing. Therefore, scientists write logically so other scientists will understand the results.**
18,2	**B.**	**because scientific hypotheses are personal views or guesses and thus are not logical. Scientists, therefore, write logically so other scientists will understand the results.**
8,5	**C.**	**Scientists usually don't want to give away "the recipe" but they do want to tell the world about their results. So they write it up logically but in a way that does not reveal how it was actually done.**
4,2	**D.**	**It depends. Sometimes scientific discoveries happen by accident. But other times discoveries happen in a logical orderly way, just like the articles are written.**
		Articles are written in a logical way showing how the actual work was done:
12,1	**E.**	**because a scientist's work is conducted logically; otherwise, it would not be useful to science and technology.**
2,4	**F.**	**because scientists do work in a logical way so that their published report will be easier to write in a logical way.**
4,2	**G.**	**Articles are not necessarily written in a logical way. They're written the work was done. This can be complicated or straightforward.**

Naive: 22,9% **Has Merit: 8,5 %** **Realistic: 59,4%**

Item 13 was related with scientists' errors in their work. Alternatives D and E (about 65%) selected by preservice science teachers were realistic. According to results on Table 4.13, majority of the preservice science teachers held realistic views about inevitable characteristics of errors. Preservice science teachers selecting alternatives A and B (about 16%) disregarded the fact that scientists are human beings. Humans make mistakes and learn from them, many things are learned with the method of trial and error.

Table 4.13. Percentage of preservice science teachers' responses to item 13.

Scientists should NOT make errors in their work because these errors slow the advance of science.		
%		***Your Position, Basically:***
8,5	**A.**	**Errors slow the advance of science. Misleading information can lead to false conclusions. If scientists don't immediately correct the errors in their results, then science is not advancing.**
7,3	**B.**	**Errors slow the advance of science. New technology and equipment reduce errors by improving accuracy and so science will advance faster.**
	Errors CANNOT be avoided:	
15,2	**C.**	**so scientists reduce errors by checking each others' results until agreement is reached.**
61,2	**D.**	**some errors can slow the advance of science, but other errors can lead to a new discovery or breakthrough. If scientists learn from their errors and correct them, science will advance.**
3,6	**E.**	**Errors most often help the advance of science. Science advances by detecting and correcting the errors of the past.**

Naive: 15,8% **Has Merit: 15,2%** **Realistic: 64,8%**

Precision and Uncertainty in Scientific/Technological Knowledge (Item 14)

Item 14 investigated the views about precision and uncertainty in scientific/technological knowledge. About half of the preservice science teachers (about 53% selected A and B alternatives) were aware of the uncertainty of scientific knowledge and predictions made by scientists and engineers and so it may be concluded that they had realistic views. Only about 6% of preservice science teachers (alternative E) held naive views about predictions, they believed that if there was accurate knowledge and enough information then predictions had to be certain. About 36 % of the respondents were between two viewpoints (Table 4.14).

Table 4.14. Percentage of preservice science teachers' responses to item 14.

%		Even when making predictions based on accurate knowledge, scientists and engineers can tell us only what *probably* might happen. They cannot tell what will happen for certain.
%		***Your Position, Basically:***
		Predictions are NEVER certain:
27,3	**A.**	**because there is always room for error and unforeseen events which will affect a result. No one can predict the future for certain.**
25,5	**B.**	**because accurate knowledge changes as new discoveries are made, and therefore predictions will always change.**
30,9	**C.**	**because a prediction is not a statement of fact. It is an educated guess.**
5,5	**D.**	**because scientists never have all the facts. Some data are always missing.**
5,5	**E.**	**It depends. Predictions are certain, only as long as there is accurate knowledge and enough information.**

Naive: 5,5% **Has Merit: 36,4%** **Realistic: 52,8%**

Logical reasoning (Item 15)

Knowledge rather than views of preservice science teachers about cause-and-effect (logical reasoning) relationships were investigated by the use of Item15. According to Table 4.15, the majority of the participants (67%) knew cause-and-effect relationships (alternatives B and C). On the other hand, about 30% of the preservice science teachers were unaware of these relationships.

Table 4.15. Percentage of preservice science teachers' responses to item 15.

If scientists find that people working with asbestos have twice as much chance of getting lung cancer as the average person, this must mean that asbestos causes lung cancer.		
%		***Your Position, Basically:***
7,9	**A.**	**The facts obviously prove that asbestos causes lung cancer. If asbestos workers have a greater chance of getting lung cancer, then asbestos is the cause.**
		The facts do NOT necessarily mean that asbestos causes lung cancer:
27,4	**B.**	**because more research is needed to find out whether it is asbestos or some other substance that causes the lung cancer.**
39,6	**C.**	**because asbestos might work in combination with other things, or may work indirectly (for example, weakening your resistance to other things which cause you to get lung cancer).**
14,6	**D.**	**because if it did, all asbestos workers would have developed lung cancer.**
2,4	**E.**	**Asbestos cannot be the cause of lung cancer because many people who don't work with asbestos also get lung cancer.**

Naive:24,9% **Realistic: 67%**

Fundamental Assumptions for All Science (Item 16)

Item 16 was dealing with the topic of science and supernatural being or deity. The results in Table 4.16 provide intriguing insights into preservice science teachers' responses. About 34% of preservice science teachers sided with the scientific community by acknowledging that the uniformitarianism assumption is central to science by selecting alternatives A and B. Of these preservice science teachers, 22 % reasoned that science was one way of knowing about the world (alternative A in Table 4.16) and a further 12,2% expressed a superficial reason for their unifomitarianism view (alternative B). An equally small number of preservice science teachers (about 7%) on the other hand, believed that science was not limited and that scientists could investigate the supernatural (alternative E). By far the largest group (about 41%), however, subscribed to a view consistent with a creationist posture and in direct conflict with the tenets of the epistemology of science-'that a supernatural being could alter the natural world (alternatives C and D).

Table 4.16. Percentage of preservice science teachers' responses to item 16.

%		Science rests on the assumption that the natural world can *not* be altered by a supernatural being (for example, a deity).
		Your Position, Basically:
		Scientists assume that a supernatural being will NOT alter the natural world:
22,0	**A.**	**because the supernatural is beyond scientific proof. Other views, outside the realm of science, may assume that a supernatural being can alter the natural world.**
12,2	**B.**	**because if a supernatural being did exist, scientific facts could change in the wink of an eye. BUT scientists repeatedly get consistent results.**
12,2	**C.**	**It depends. What scientists assume about a supernatural being is up to individual scientists.**
28,7	**D.**	**Anything is possible. Science does not everything about nature. Therefore, science must be open-minded to the possibility that a supernatural being could alter the natural world.**
6,7	**E.**	**Science can investigate the supernatural and can possibly explain it. Therefore, science can assume the existence of supernatural beings.**

Naive: 47,6% **Realistic: 34,2%**

Epistemological Status of Scientific Knowledge (Item 17, 18 and 19)

Item 17 revealed whether preservice science teachers viewed laws as discoveries or inventions while investigating their views on characteristics of laws. In Table 4.17, it may be seen that most of the preservice science teachers (about 70%) viewed laws as discoveries which reflected an ontological view supported by the logical positivists by selecting alternatives A, B, and C. About 18% of the respondents gave a realistic answer to that question by selecting alternative E which was an epistemological viewpoint with the contemporary literature. On the other hand, alternative D is an erroneous view that media uses, selected by 6,6% of the whole respondents.

Table 4.17. Percentage of preservice science teachers' responses to item 17.

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific LAWS. Others think that scientists invent them. What do you think?		
%		***Your Position, Basically:***
	Scientists discover laws:	
32,5	**A.**	**because the laws are out there in nature and scientists just have to find them.**
18,1	**B.**	**because the laws are based on experimental facts.**
19,3	**C.**	**but scientists invent the methods to find those laws.**
6,6	**D.**	**Some scientists may stumble onto a law by chance, thus discovering it. But other scientists may invent the law from facts they already know.**
18,1	**E.**	**Scientists invent laws, because scientists interpret the experimental facts which they discover. Scientists don't invent what nature does, but they do invent the laws which describe what nature does.**

Naive: 76,5% **Realistic: 18,1%**

When in item 17, the term law was replaced by the terms "hypothesis" and "theory", preservice science teachers expressed very similar to their views on scientific theories. Therefore, the next two items were similar, responses given to them were also similar, and so they may be analyzed together.

In item 18, the participants were asked whether hypotheses were discoveries or inventions and in item 19, it was asked whether theories were discoveries or inventions. About 61% of the whole respondents for item 18 (Table 4.18) and about 60 percent of the whole respondents for item 19 (Table 4.19) had ontological views which were inconsistent with contemporary views by selecting A, B, C, and D alternatives. On the other hand, about 33% (alternatives E and F) of the respondents in item 18 and about 31% (alternatives E and F) of the respondents in item 19 held contemporary views about nature of theories and hypotheses.

Table 4.18. Percentage of preservice science teachers' responses to item 18.

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific HYPOTHESES. Others think that scientists invent them. What do you think?		
%		***Your Position, Basically:***
		Scientists discover a hypothesis:
27,1	**A.**	**because the idea was there all the time to be uncovered.**
11,4	**B.**	**because it is based on experimental facts.**
14,5	**C.**	**but scientists invent the methods to find the hypotheses.**
8,4	**D.**	**Some scientists may stumble onto a hypothesis by chance, thus discovering it. But other scientists may invent hypothesis from facts they already know.**
		Scientists invent a hypothesis:
21,7	**E.**	**because a hypothesis is an interpretation of experimental facts which scientists have discovered.**
11,4	**F.**	**because inventions (hypothesis) come from the mind-we create them.**

Naive: 61,4% **Has Merit: 21,7%** **Realistic: 11,4%**

Table 4.19. Percentage of preservice science teachers' responses to item 19.

For this statement, assume that a gold miner "discovers" gold while an artist "invents" a sculpture. Some people think that scientists *discover* scientific THEORIES. Others think that scientists invent them. What do you think?		
%		***Your Position, Basically:***
	Scientists discover a theory:	
15,9	**A.**	**because the idea was there all the time to be uncovered.**
16,5	**B.**	**because it is based on experimental facts.**
20,1	**C.**	**but scientists invent the methods to find the theories.**
7,3	**D.**	**Some scientists may stumble onto a theory by chance, thus discovering it. But other scientists may invent theory from facts they already know.**
	Scientists invent a theory:	
28,0	**E.**	**because a theory is an interpretation of experimental facts which scientists have discovered.**
3,0	**F.**	**because inventions (theories) come from the mind-we create them.**

Naive: 59,8% **Has Merit: 28%** **Realistic: 3%**

Paradigms versus Coherence of Concepts across Disciplines (Item 20 and 21)

According to item 20, only about 18% of preservice science were realistic or had a contemporary view on the nature of scientific ideas. Views of preservice science teachers selecting alternatives C, D, and E (57,9%) were inconsistent with contemporary views about scientific ideas. Alternative B selected by about 16% of the preservice science teachers, which was very close to contemporary views (Table 4.20).

Table 4.20. Percentage of preservice science teachers' responses to item 20.

Scientists in different fields look at the same thing from very different points of view (for example, H^+ causes chemists to think of acidity and physicists to think of protons). This makes it difficult for scientists in different fields to understand each others' work.		
%		***Your Position, Basically:***
		It is difficult for scientists in different field to understand each other:
17,5	**A.**	**because scientific ideas depend on the scientists' viewpoint or on what the scientist is used to.**
16,3	**B.**	**because scientists must make an effort to understand the language of other fields which overlap with their own fields.**
		It is fairly easy for scientists in different fields to understand each other:
13,3	**C.**	**because scientists are intelligent and so they can find ways to learn the different languages and points of view of another field.**
13,9	**D.**	**Because they have likely studied the various at one time.**
30,7	**E.**	**Because scientific ideas overlap from field to field. Facts are facts no matter what the scientific field is.**

Naive: 57,9% **Has Merit: 16.3%** **Realistic: 17,5 %**

In item 21, parallel to item 20, the meanings of the scientific ideas were asked. The alternative A (about 25%) selected by preservice science teachers was the most realistic or contemporary view. Alternative B selected by about 28% of the whole respondents was very close realistic view. Views of preservice science teachers selecting alternatives C, D, and E (about 42%) were not consistent with contemporary views about the nature of scientific ideas (Table 4.21).

Table 4.21. Percentage of preservice science teachers' responses to item 21.

%		Scientists in different fields look at the same thing from very different points of view (for example, H^+ causes chemists to think of acidity and physicists to think of protons). This means that one scientific idea has different meanings, depending on the field a scientist works in.
		Your Position, Basically:
		A scientific idea will have the different meaning in various fields:
24,5	**A.**	**because scientific ideas can be interpreted differently in one field than in another.**
27,6	**B.**	**because scientific ideas can be interpreted differently, depending on the individual scientist's point of view or on what the scientist already knows.**
		A scientific idea will have the same meaning in all fields:
22,1	**C.**	**because the idea still refers to the same real thing in nature, no matter what point of view the scientist takes.**
8,6	**D.**	**because all sciences are closely related to each other.**
11,7	**E.**	**in order to allow people in different fields to communicate with each other. Scientists must agree to use the same meanings.**

Naive: 42,4% **Has Merit: 27,6%** **Realistic: 24,5%**

4.2. Analysis of Interviews

In this study, to identify the preservice science teachers' views on the n ature of science details, nine individual interviews were conducted with the preservice science teachers (three females and six males) from METU. The selection of the participants depended on the willingness of the preservice science teachers to take part in the present study. The headings of questşons and the answers given by the participants for these questions were given below.

Definition of Science

When asked the definition of science no consensus about the definition of science was observed. Answers were quiet different. Every respondent gave his/her own definition. They defined science as: life; understanding truths and putting them in an order; an area seeking answers and unknowns; investigations, improvements, making laws and method sequence; putting the information into an order; knowledge; provable truths; application of technology; and reflections from the observations of nature. Results displayed a range of views on science definition starting from knowledge or truths to the process of ordering the knowledge, truths or observations. Two of the respondents defining science stated that:

> 'Science is to produce knowledge not only by observations but also by using some data with the help of instruments (Participant 3, Male)…"
>
> "… The aim of science is to find out the unknown things in n ature and to state the laws about them (Participant 5, Male)…"

Majority of the respondents (77%) stated the differences between science and other disciplines in the same way. They claimed that science is concrete but other disciplines, such as religion and philosophy, are abstract. One participant said that:

> "…Positive sciences such as biology, physics and chemistry have some concrete reality and they may be proved with the experiments. On the other hand, religion and philosophy change depending on the people ideas (Participant 9, Female)..."

In addition to these one respondent explained the dogmatic characteristic of religion and philosophy, and the other respondent claimed that religion and philosophy are the fundamentals of science.

Definition of Experiment

All of the participants agreed on that the development of scientific knowledge require experiments. In addition to this, about 77% of the participants defined the experiments in the same way. They explained the experiments as a process to prove scientific knowledge (hypothesis or theories). One of the respondents claiming this view by stating that:

"..experiments are necessary. For example at the beginning of the genetic, Mendel first investigated and did some experiments on peas. If he did not do these experiments, he would not state a theory. Therefore, after a hypothesis, to prove or to refute it, experiments are necessary (Participant 5, Male)..."

On the other hand, two of the respondents defined experiment differently. They claimed that experiment is repeating the natural phenomena in laboratory conditions to strength an opinion controlling the parameters. One of them said that:

"..experiment is to test an event in laboratory conditions. Because if we want to observe an incident in nature, we have only one chance. But in the laboratory, we have a chance to control the parameters (Participant 8, Male)..."

The Scientific Method

More than half of the respondents (66%) claimed that there is one method followed by scientists during the scientific investigations. They defined the method as the way most of science books wrote; observations, hypothesis, experiments, theories and law. One of the respondents explained her view as:

"..first an assumption is stated and then using experiments it is proved and i t becomes a theory, if theory is proved and become fact then theory becomes law. Scientific method should exist otherwise a chaos can be observed. Scientists should use an international scientific method to avoid confusion. In this way, science becomes certain and does not change from society to society (Participant 9, Female)..."

On the other hand, 33% of the respondents have some suspicions on this subject. One of the respondents claimed that there may be other scientific methods that he does not know exactly their content. One of the participant also said that, there is one scientific method but she thought that it is not unique. Another respondent claimed that there is a scientific method but scientists may omit some steps of this method.

Nature of Scientific Models and Classification Schemes

Almost half of the participants (55%) claimed that scientific models and scientific classifications are not copies of reality. Indeed, they explained their assertion that scientific models and scientific classifications are similar to reality or we can say close to reality but not the same. One of the preservice science teachers advocated this view as:

> "..scientists do these classifications and models to make their study easy. In periodic table and classifications of organisms, scientists group the same things and differences between them become easy. Also in atomic model, there is a nucleus in the middle of it and there are electrons around it, but I think in reality there must be some differences (Participant 1, Male)..."

Two of the respondents answered this question different from the others and they said that scientific models and scientific classifications are copies of reality. One of them claimed that:

> "..they are copies of reality. Because they are done to show th e things in nature. For example, with the help of electron microscope, we can see the DNA. The model of DNA is the same with the reality (Participant 5, Male)..."

Another two of the respondents stated that scientific models are copies of reality but scientific classifications are not copies of reality.

Scientific Theories and Scientific Laws

All the preservice science teachers were agreeing on that scientific theories are not certain, but scientific laws are certain. Four of the respondents also stated that all the theories become laws, so laws are developed from the theories. One of them stated that:

> "..scientific laws are developed from scientific theories. First a hypothesis is proved and become a theory. After many years theories become scientific laws, this is the main difference between scientific laws and theories (Participant 7, Male)..."

In addition to this, other five of the respondents claimed that theories can not be refuted but also not accepted completely. One of the participants stated that:

> "... scientific laws cannot be refuted, but we have chance to refute the scientific theories, such as evolution theory. It became a theory but there are some missing points to become a law. On the other hand, gravitational force law cannot be changed and it can be proved in many ways (Participant 9, Female)..."

Tentativeness of Scientific Theory

All the preservice science teachers stated that scientific theory changes. While explaining the reasons, four of the respondents also stated that developments in technology affect the scientific knowledge and so the theories and the science can change.

> "..They change, they can be changed. Because for example, atomic theory has been changed many times during the years. Lastly, I think Bohr atomic theory is used..scientists try to reach the most truth knowledge and with the improvements in technology, science can change (Participant 1, Male).."

Other five of the respondents claimed that to understand the nature and the human characteristics deeply, theories are improved so they change. One of the respondents explained it in that way:

> "..I think atomic theory and also evolution theory will certainly change. Because geographic characteristics of world will change. In addition to this scientists will continue to study on nature and human characteristics (Participant 2, Female)..."

Scientists' Effects on Scientific Knowledge

In this question, six respondents out of nine stated that some scientists' characteristics affect these controversies in science when scientists use the same set of available data. Four of them emphasized that differences in scientists' education, personality, background, and environments cause the changes in their studies. In addition to this, two of them claimed the difference in scientists' imagination is the reason for these differences in their conclusions. Two of them stated their opinion in that way:

> "..people are different from each other, their views are also different, so this is normal. Because people get a point of view on some issues depending on their life styles. Also environmental effects, educational effects, and may be geographical effects are important. One may be interested in physics, and another one may be interested in biology (Participant 5, Male).."

"..for example, one scientist may be liv e around a volcano and he realize the results of a volcanic eruption. Another may observe a meteor falling on to ground. Therefore their life experience may affect them. Because science needs to produce some scenarios and also depend on the imagination (Participant 8, Male).."

On the other hand, three of the respondents answered this question differently. One of them emphasized the differences in their experiments. The other respondent comments on these differences were due to the insufficient technology. One respondent also stated that if a study is unobservable then these differences are normal.

Social and Cultural Values in Science

When asked whether social and cultural values affect the science or not, almost 44% of the preservice science teachers stated that science is universal and science is independent from society. Two of them also added that only technology changes from society to society. One of them explained his view:

"... science is universal, but technology part can be changed from society to so ciety. Technology is done differently according to society... DNA double helix model do not change in different societies, but scientists view may change depending on his/her culture (Participant 7, Male).."

Other 33% of the respondents claimed that science changes in different cultures. One of them stated that:

"..in every society, people's approaches to science and technology are different. In our society one scientific knowledge or technological development may be popular, but in other country a different scientific knowledge or technological development may be popular. So it changes (Participant 1, Male).."

Two of the respondents have answered this question differently. One of them claimed that scientific theories change in different cultures but scientific laws do not change depending on the culture. The other one have some confusion on this question and he said science is both universal and affected from the society.

Scientific Disciplines

All the participants answered this question in the same way. All of them claimed that biology, physics and chemistry are related each other. Especially four of them stated that science is composed of biology, physics and chemistry. One of them opinion is:

> "..They are certainly related. We cannot separate them from each other. Probably there are some points that they come together. We cannot think physics without mathematics. We can combine mathematics and physics with chemistry. They are all scientific. Science arises from people's problem..so there is integrity among the m. Science is composed of them (Participant 3, Male).."

In addition to this, two of the participants' reasons about this relation are different to others. They emphasized that they are related but physics is more important than the chemistry and biology.

Certainity of Science

The most popular answer to this question was that theories can change but laws cannot. Four of the respondents answered the question in this way. One of the preservice science teachers explained it as:

> "..if a scientific knowledge bec ome a law after a hypothesis and a theory and also if it is accepted by everyone, then this scientific knowledge is certain. But to be certain, a long time is needed. Scientific theories and hypothesis can change..and although scientists use their subjectivity, results are objective (Participant 1, Male).."

Two of the participants stated that science may be certain only for today but in time science may be change. One stated that:

> "..science has a definite characteristic but only for today. Today's unknown thi ngs may be known tomorrow. Therefore the certainty of science may be changed. In time it will change (Participant 5, Male).."

Other two of the participants have different ideas from others. One said that scientific truths cannot change but scientific data can change. The other also stated that with the improvements in technology, science become concrete and certain.

Only one of the respondents stated that science is certain and unchangeable. She stated that:

> "..we can say it is certain. Because science doe s not create anything that does not exist in nature. Science tries to make meaningful of some existence of things in the nature. If I remain on the ground, there is a gravitational force. It is impossible to change this (Participant 9, Female).."

Results of the interview enlightened several points about the views of the participants on nature of science issue. According to these results, it can be said that preservice science teachers have some traditional views on some topics but they also have some contemporary views on some other topics.

4.3. Misconceptions on Nature of Science

Although the purpose of this study is not directly to state the misconceptions of preservice science teachers, results of interview revealed some misconceptions of participants on nature of science (Table 4.22).

Table 4.22. Misconceptions on Nature of Science

Hypotheses become theories that in turn become laws.
Scientific laws and other such ideas are absolute.
A general and universal step-by-step scientific method exists.
Science and its methods can answer all questions.
Scientists are objective.
Experiments are the principal route to scientific knowledge.
Science models represent reality.
Science is not affected from cultures.

CHAPTER 5

DISCUSSIONS, IMPLICATIONS AND RECOMMENDATIONS

This study aimed at investigating the views of preservice science teachers on nature of science issues. This chapter presents discussions of the results, implications and recommendations for practice and future studies.

5.1. Discussions

Results of this study are in agreement with the studies reported in the literature (Bell, Blair, Crawford, Lederman, 2003; Yalvac & Crawford, 2002; Tairab, 2001; Brickhouse, Dagher, Letts & Shipman, 2000; Haidar, 1999; Yakmaci, 1998; Rubba & Harkness, 1993; Pomeroy, 1993; Ryan & Aikenhead, 1992; Aikenhead, 1987). For example, the present study displayed that there was no consensus on the definition of science. The study performed by Aikenhead and Ryan (1992), and Yakmacı (1998) found the similar results with this study. According to the results of those studies, subjects did not acquire a uniform view of science. In the present study, some of the preservice science teachers were confused about the terms of science and technology, specifically medical and environmental technological investigations. Although many of the preservice science teachers defined science as a content or process, they also thought it as something to make a world better place to live in. The preservice science teachers were unaware of the social aspects of science or as a form of human cultural activity. Like many other studies (Bradford, Rubba and Harkness 1995; Botton and Brown, 1998), the present study also indicated the decisiveness on to defining technology as application of science, which is the way of most of the science books did. These definitions may result from the image of today's world. This may be the result of the fact that in recent years, science is usually reflected in technology form in our lives, it means science come our lives wearing a uniform called as technology. These results were also supported by the interviews. All of the participants gave different definitions for science. Definitions given for science changed from "life" to "application of technology". In addition to this, generally preservice science teachers emphasize that science is related with concrete concepts but other disciplines such as religion and philosophy are related with abstract concepts. Only one participant stated the "dogmatic" characteristic of religion different from science.

They have contemporary views on some items. For example, about half of the preservice science teachers have contemporary views on nature of observations which is a promising finding for this study. They thought that science actions are heavily influenced by scientists' previous values, experiences and beliefs. On the other hand, remaining are more inclined to the traditional view which see the scientists free of his/her human characteristics; as if it tries to put the scientists to a supernatural level that secures him or her from making mistakes. In addition to these, in another item majority of them stated scientists of objectivity, so in this aspect participants confused on the nature of observations. The interview results also displayed that scientists differ from each other because of differences in their environment, background, education, imagination style etc., although many participants thought the objectivity of the scientists' results. According to Kuhn even though scientists use the same instruments they had already used, and observe the same phenomenon with the same set of data, they can still see something new or even contradictory to their previous conceptions (Ryan & Aikenhead, 1992). McComas (1996) states that scientists like all other observers hold some preconceptions and biases about the world. These preconceptions influence individual scientists' observations. It must be noted that there may be selections in perceptions of the things around us. Certain facts either can not be seen by us all or are regarded as unimportant by scientist on the basis of prior values and knowledge.

Concerning the nature of scientific models and scientific classification schemes, preservice science teachers have mainly naive views about the nature of scientific models. They considered models as copies of reality although the contemporary epistemology accepts the limitations of models and regards them as aids to explanation. On the other hand, these preservice science teachers have mostly realistic views when it comes to think about the classification schemes despite of the fact that both models and classifications schemes are conceptual inventions of the scientists. It means preservice science teachers' view on the nature of scientific models is problematic; only classifications of schemes were correctly understood. When the interviews were analyzed, same result was found. About half of the participants stated that scientific models are copies of reality, but scientific schemes are not copies of reality. They claimed that with the help of experiments and some instruments we can observe the original structure of atoms and DNA which are represented with the scientific models. On the other hand, the classification schemes are not observed in nature, they are constructed to make studies easy. This result is parallel to the findings of the Yakmacı (1998), Ryan and Aikenhead (1992), and Aikenhead (1987).

The most striking and encouraging result of the present study is that most science teachers are aware of the tentative nature of science. On the other hand, in the interview part, misconception on tentativeness of science was emerged. All the participants stated that scientific theories change, but scientific laws cannot change. This misconception may be the results of textbooks or teaching methods in schools. The tentativeness of scientific knowledge; one of the main attributes of science that makes it different than the other forms of knowledge and prevents it from being dogmatic. The tentative characteristic of science explains that scientific knowledge is subjected to change with new observations, discoveries and reinterpretations of existing observations (Schwartz et al., 2000). A falsificationist position also states that science was seen to progress by disproving the scientific knowledge of the past (Ryan & Aikenhead, 1992). According to Kuhn, when scientific paradigms change, the world itself changes with them. It is not the physical world changes, but our view and understanding of it changes.

This study revealed preservice science teachers' misconceptions and lack of understandings on nature of science. Their views are mostly traditional on the nature of science. For example, one of the most important findings of this study was preservice science teachers' misconceptualization of the relationships between hypotheses, theories and laws. Most of the respondents selected a hierarchical relationship between them, but according contemporary views, they are all different kinds of statements. This finding was also supported with interviews. Majority of the participants in the interview part stated this relation as “A hypothesis is tested by experiments, if it proves correct, it becomes a theory. After a theory has been proven true many times by different people and has been around for a long time, it becomes a law.” Preservice science teachers might construct this possible dogmatic assumption and myth on relationships among hypotheses, theories and laws while they have been learning science from textbooks and in classrooms. Preservice science teachers appear to be ignorant of the fact that many laws in science were known before any theories were developed to explain them. Lederman (2004) stated that laws are statements or descriptions of the relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena.

It showed that when developing new theories or laws, scientists needed to make certain assumptions about nature so it is questioned whether these assumptions must be true or not in order for science to progress properly. While they believe tentativeness of scientific knowledge, most of the preservice science teachers thought that scientists should make true assumptions in order for science to progress, which is inconsistent with the contemporary views. It is interesting to note that, in another items related with the certainty of science, most respondents think that error is acceptable in science because these errors can be detected and corrected through the scientific progress which is consistent to realistic view. Therefore the participants did not recognize the importance of assumptions as part of science. This may be because of their beliefs about certainty of science, it means everything related with science must be true, even assumptions. These contradictions between the results showed that there are some suspicious on this subject.

Preservice science teachers generally took part in the favor of simplicity of scientific knowledge which is consistent with the contemporary views. On the other hand some preservice science teachers still believed that complexity was the prerequisite for the quality of a theory.

When the preservice science teachers were asked about the nature of scientific method, they tended to hold a vague preconception that the scientific method was "questioning, hypothesizing, collecting data, and concluding." None of the respondents embraced the pragmatic view the scientists use any method that might get results. In addition to this, in another item related with nature of scientific method, most of the participants also agreed on that there is a definite pattern to doing science, which is consistent with traditional view. In the interview part, majority of the participants also stated one way of doing science and explained a hierarchical relationship of the hypotheses, theories, and laws as a scientific method. This finding is not surprising because like many other countries, in Turkey, the scientific method is taught in schools with a hierarchical relationship. Over the years epistemologist have generally agreed that there is no such thing as "scientific method"- that five-step or seven-step description of how to do science, included in chapter one of most science textbooks (see Ryan & Aikenhead, 1992). A more critical description would characterize the method as an algorithm that students are expected to memorize, recite, and follow as a recipe for success. Teachers, textbooks, and teaching method, as well as evaluation system enforce this concept. The visions of reform, however, are quick to point out that there is no single fixed set or sequence of steps that all scientific investigations follow. The contemporary view of scientific inquiry advocated is that the questions guide the approach and the approaches vary widely within and across scientific disciplines and fields (Lederman, 2004).

Another promising finding of this study is that the majority of participants were aware of the cause-and-effect relationships about the scientific and technological issues. This finding may be because of emphasizing in science education curriculum on cause-and-effect relations. This result gave some hopes to the positive effects of science education and may be a base for the development of a system to include more people into science education to be literate both scientifically and technologically.

When it comes to fundamental assumptions for all science, interestingly half of the participants believed that science may accept that a supernatural being can alter the world. On the basis of this result, and the results from other items related with this issue, one can say that in general the Turkish preservice science teachers were not well informed about the assumption in science. The respondents in this study appeared to hold misconceptions of fundamental assumptions for all science similar to those reported by Yakmacı (1998). Preservice science teachers' religious background also influences this result. Their naive preconceptions could easily make them susceptible to fallacious argument, such as those of creationist, and cause them difficulty in constructing scientific concepts. This result must be studied on deeply, but for now, we can say that it is disappointed for our future.

In the present study, three items investigated inventive characteristics of scientific knowledge (hypotheses, theories and laws). Most of the preservice science teachers see scientific knowledge as discoveries that are not contemporary views. According to realistic view, scientists do not invent what nature does, but they do invent the laws, theories and hypotheses which describe what nature does. Understanding how science operates is imperative for evaluating the strengths and limitations of science, as well as the value of different types of scientific knowledge. For instance, preservice science teachers may understand the atomic model, Boyle's law, and evolutionary theory, but may not understand what law, theory, and model mean in the discipline of science (Lederman, 2004).

Concerning the paradigms versus coherence of concepts across disciplines, more participants have a naive view on saying scientific ideas refers to the same thing in nature, regardless of the discipline of the individual scientist. On the other hand, a number of preservice science teachers supported that scientific ideas are interpreted differently according to the scientist's point of view or on what the scientist already knows. Scientific ideas may be interpreted differently in one field than in another, this is actually one claim of Kuhn about paradigm shifts (Ryan & Aikenhead, 1992).

The present study also indicated that preservice science teachers are not aware of the effects of cultural values on science. Interview results showed that they believe highly on certainty of science so they do not consider on the societies. It is accepted that social, cultural and political interests of any dominant group within the society play an important role in making scientific knowledge and its decision processes. Yalvac and Crawford (2002) draw attention to the so-called external factors (i.e. racism, sexism, ideologies, and politics) in the development of knowledge. Values of society shape the proponents of the integrity of science and so science itself is the extension of society in terms of its discourses. Ethics and values that influence science and scientific researches are the parts of the nature of science. The nature of science issues also include that science is a human endeavor influenced by the culture in which it is practiced. So, different cultures may view the same phenomena but interpret them differently.

5.2. Implications

Primary aim of science education is to train scientifically literate individuals for a healthy and developing society. To achieve that, science teachers must be scientifically literate at first. The nature of science is one of the most important dimensions of scientific literacy. Therefore, science teachers must possess contemporary views about the nature of science. This study gives insights about the views of preservice science teachers on nature of science. According to the results of the present study, it may be concluded that preservice science teachers held inconsistent views on nature of science issue. For this reason, some interventions must be made in order to improve the situation.

Being science educators, our aim should be able to teach science as well as we can, and reduce the possible dogmatic assumptions and myths of science that students may construct while they are learning science from textbooks and in classrooms. Teaching the nature of science is essential to reducing the myths on science that students may construct while they are learning science.

According to the picture that we get from the results, teacher training programs must give place to courses on philosophy and history of science and emphasize contemporary philosophies of science. In addition to this, teacher training program should be revised to improve the way that how this nature of science issue can be introduced to the students from any levels of education. The Ministry of Education should include a goal emphasizing the importance of nature of science.

We need to address the aforementioned aspects of the nature of science in our preparation of science teachers. Although it is easy to suggest that science teachers should make realistic views of science more explicit to their students, specific instructional methods are needed for teachers to do a better job. Ryan (1992) outlines how VOSTS items themselves can be used in science classrooms for diagnostic, assessment, and evaluation purposes. Aikenhead (1988) offers an instruction guide for teaching science through a Science-Technology-Society approach. Central to such an approach are instructional strategies (such as small group work, student-centered discussions, simulations, and decision making) that provide concrete opportunities for teachers to make realistic views of science more explicit to students.

The role of ethics and values in science were not meaningfully understood by preservice science teachers. The role of ethics and values entering into and exported from science and technology should be addressed in science education.

Effective procedures for clarifying the nature of science could be incorporated in science and science methods units in teacher education programs. It would appear necessary for teacher education programs to provide additional staff development to supervising teachers regarding the nature of science.

During the life of students' education, students should be prepared to give decisions on socio-scientific issues. Therefore, students should understand the nature and importance of science for societies. A conscious society on science brings conscious individuals to the education.

5.3. Recommendations

On the basis of findings of this study, the following recommendations can be given:

This study was conducted at only three universities in Ankara. Thus to increase the generalizability of the results, it is worth to conduct similar studies in different universities of Turkey.

In this study the sample was preservice science teachers. It is also necessary to conduct studies on elementary science teachers, biology, physics and chemistry teachers. Additionally, studies conducting with the people from other fields of study, such as all natural and social sciences departments would be helpful to get much more information.

The present study displayed that there may be some problems about curriculum. Thus another study can be conducted to explore these problems deeply and compare with other countries' curricula.

This study was conducted with descriptive technique to investigate the views of preservice science teachers on nature of science. An inferential study can be conducted with a larger sample to support the findings of this study.

This study may be evaluated as one of the few studies which try to reveal preservice science teachers' views on nature of science in Turkey. By taking this one as a basis, some further studies are recommended. After this study, first attempt may be to develop teacher education programs emphasizing the nature of science issue.

Moreover, researchers may attempt to assess the primary and high school students', their science teachers', university professors' and other preservice science teachers' views on nature of science.

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APPENDIX A

VOSTS-T

Sayın Öğretmen Adayları

Bu anket, öğretmen adaylarının **bilimin doğası** konusuna yönelik düşüncelerini anlamak amacıyla hazırlanmıştır. Öğretmen adayı olarak vereceğiniz cevaplar, öğretmen yetiştirme programlarının geliştirilmesine önemli katkılarda bulunacaktır. Sizlerin görüşleri bizler için çok önemlidir. Yardımlarınız için teşekkür ederiz.

Yrd. Doç. Dr. Ceren Tekkaya, Yrd. Doç. Dr. Jale Çakıroğlu, Rahşan Erdoğan

AÇIKLAMALAR

Bilimin Doğası konusuna yönelik bu anket her sayfaya bir soru gelecek şekilde düzenlenmiştir. Her soru **bilimin doğası** konusunda bir cümle ile başlamaktadır. Bu cümle genellikle temel bir görüş bildirmektedir.

Konu hakkındaki farklı görüş veya durumlar seçeneklerde sıralanmıştır. Her soru için düşüncenize uygun olan **BİR TEK SEÇENEĞİ** işaretleyiniz.

Bu ankette doğru yanıt yoktur. Burada amaç sadece sizin bilimin doğası konusundaki görüşlerinizi öğrenmektir.

KİŞİSEL BİLGİLER

1. Üniversitenizin Adı: ____
2. Cinsiyetiniz: ☐ Kız ☐ Erkek
3. Doğum tarihiniz (yıl): _______________
4. Genel not ortalamanız (üniversite, GPA): _________
5. Mezun olduğunuz lise türü: ☐ Düz Lise ☐ Anadolu Lisesi ☐ Meslek Lisesi ☐ Anadolu Öğretmen Lisesi ☐ Diğer___________
6. Üniversite eğitiminiz süresince Bilim, Teknoloji ve Toplum dersini aldınız mı?
   ☐ Evet ☐ Hayır
7. Üniversite eğitiminiz süresince aldığınız fen derslerini belirtiniz.
   ☐ Fizik ☐ Kimya ☐ Biyoloji ☐ Astronomi
   ☐ Jeoloji ☐ Zooloji ☐ Botanik
   ☐ Diğer (Lütfen belirtiniz) ……………………………………..…

1. Bilimi tanımlamak zordur; çünkü bilim, karmaşıktır ve birçok konuyla ilgilidir. Fakat bilim asıl olarak:

A. Biyoloji, fizik ve kimya gibi konularda çalışmaktadır.
B. Yaşadığımız dünyayı (maddeyi, enerjiyi ve yaşamı) açıklayan prensipler, kanunlar ve teoriler gibi bilgilerdir.
C. Dünyamız ve evren hakkında bilinmeyenleri araştırmak, yeni şeyleri ve nasıl çalıştıklarını keşfetmektir.
D. Yaşadığımız dünya ile ilgili problemleri çözmek için deneyler yapmaktır.
E. Bir şeyler icat etmek ya da tasarlamaktır (yapay kalpler, bilgisayarlar ve uzay araçları gibi).
F. Bu dünyayı yaşam için daha iyi bir yer yapmada gerekli olan bilgiyi bulma ve kullanmadır (hastalıkları tedavi etmek, kirliliği çözümlemek ve tarımı geliştirmek gibi).
G. Yeni bilgileri keşfetmek için fikir ve tekniklere sahip olan insanların (yani bilim adamlarının) bir arada olduğu organizasyondur.

H. Hiç kimse bilimi tanımlayamaz.

I. Anlamadım
J. Bir seçim yapmak için yeterli bilgiye sahip değilim.
K. Seçeneklerin hiçbiri kişisel görüşlerimi yansıtmıyor.

2- Eğer yetenekli bilim adamları farklı teorilere inanıyorlarsa yaptıkları gözlemler de farklı olacaktır.

A. Evet, çünkü bilim adamları farklı yöntemler kullanarak deney yapacaklar ve farklı şeylere dikkat edeceklerdir.
B. Evet, çünkü bilim adamları birbirlerinden farklı düşünecekler ve bu da onların gözlemlerini farklılaştıracaktır.

C. Bilim adamları farklı teorilere inansalar da bilimsel gözlemler çok fazla değişmez. Bilim adamları gerçekten yetenekliyse gözlemleri de benzer olacaktır.

D. Hayır, çünkü gözlemler olabildiğince kesindir. Bilim bu şekilde gelişir.
E. Hayır, gözlemler gördüklerimizden başka bir şey değildir ve gerçektir.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

3. Araştırma laboratuvarlarında kullanılan bir çok bilimsel model (örneğin DNA modeli ve atom modeli) gerçeğin kopyalarıdır.

A. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bilim adamları, bu modellerin doğru olduğunu söyler, öyleyse onların doğru olmaları gerekir.
B. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bir çok bilimsel kanıt onların gerçek olduğunu kanıtlamıştır.
C. **Bilimsel modeller, gerçeğin kopyalarıdır;** çünkü bilimsel modeller hayatın gerçekleridir. Amaçları bize gerçekleri göstermek veya bize bu gerçekler hakkında bir şey öğretmektir.

D. Bilimsel modeller, bilimsel gözlem ve araştırmalara dayandığından hemen hemen gerçeğin kopyalarıdır.

E. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü bilimsel modeller sadece kendi sınırlılıkları içinde öğrenme ve açıklamaya yardım eder.
F. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü teoriler gibi, bilimsel modeller de zamana ve bilgimizin durumuna göre değişir.
G. **Bilimsel modeller, gerçeğin kopyaları değildir;** çünkü gerçeğin göremeyeceğinizden dolayı bu modeller düşünce ya da tahminlerden oluşur.

H. Anlamadım.
I. Bir seçim yapmak için yeterli bilgiye sahip değilim.
J. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

4. Bilim adamları sınıflandırma yaparken (örneğin türlerine göre bitkileri, periyodik tabloya göre bir elementi, kaynağına göre enerjiyi ya da büyüklüğüne göre bir yıldızı) doğada olduğu gibi sınıflandırırlar. Bundan başka bir yol yanlış olurdu.

A. **Çünkü sınıflandırmalar, doğadaki gerçek şekle birebir uyar.** Bilim adamları yıllar boyunca çalışmalarıyla bu sınıflandırmaları kanıtlamışlardır.
B. **Çünkü sınıflandırmalar, doğadaki gerçek şekle birebir uyar.** Bilim adamları, sınıflandırma yaparken gözlenebilir özellikleri kullanırlar.
C. Bilim adamları, doğayı en basit ve mantıklı yolla sınıflandırırlar, ama kullandıkları yol her zaman tek yol değildir.

D. Doğayı sınıflandırmanın bir çok yolu vardır, ama bir **evrensel sistem** üzerinde anlaşmak bilim adamlarının çalışmalarındaki karışıklıkları önler.

E. **Doğayı sınıflandırmanın başka doğru yolları olabilir.** Çünkü bilim, değişikliklere uğrayabileceğinden yeni keşifler farklı sınıflandırma sistemlerine yol açabilir.
F. **Hiç kimse doğanın gerçek şeklini bilemez.** Bilim adamları, doğayı algılamalarına göre veya teorilere göre sınıflandırırlar. Bilim asla kesin değildir ve doğa çok çeşitlidir. Bundan dolayı, bilim adamları birden çok sınıflandırma sistemini doğru olarak kullanabilir.

G. Anlamadım.
H. Bir seçim yapmak için yeterli bilgiye sahip değilim.
I. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

5. Bilim adamlarınca yapılan araştırmalar doğru olarak yapılsa bile, araştırma sonunda vardıkları bulgular gelecekte değişebilir.

A. **Bilimsel bilgi değişir;** çünkü bilim adamları, kendilerinden önceki bilim adamlarının teorilerini ya da buluşlarını çürütür. Bilim adamları bunu yeni teknikleri ve gelişirilmiş araçları kullanarak, daha önce gözden kaçırılmış faktörleri bularak veya ilk araştırmadaki hataları ortaya çıkararak yaparlar.
B. **Bilimsel bilgi değişir;** çünkü eski bilgiler yeni buluşların ışığında yeniden yorumlanır. Bilimsel gerçekler değişebilir.

C. **Bilimsel bilgi değişir gibi görünür** çünkü eski gerçeklerin yorumu veya uygulaması değişebilir. Doğru şekilde yapılan deneyler **değişmez** gerçeklere yol açar.
D. **Bilimsel bilgi değişir gibi görünür** çünkü eski bilgilere yeni bilgiler eklenir; eski bilgiler aslında **değişmez.**

E. Anlamadım.
F. Bir seçim yapmak için yeterli bilgiye sahip değilim.
G. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

6. Bilimsel düşünceler, hipotezlerden teorilere doğru gelişir; ve sonuçta yeterince güçlüyseler bilimsel kanun olurlar.

A. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bir hipotez deneylerle test edilir, eğer doğruluğu **kanıtlanırsa** teori olur. Teori bir çok defa ve uzun zaman boyunca farklı insanlar tarafından test edilip **kanıtlanırsa** kanun olur.
B. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bir hipotez deneylerle test edilir, eğer **destekleyen kanıtlar** varsa teori olur. Bir teori bir çok defalar test edilip **doğru olduğu görülürse** bu teorinin kanun olması için yeterlidir.
C. **Hipotez teoriye, teori kanuna dönüşebilir;** çünkü bilimsel düşüncenin gelişmesi için bu mantıklı bir yoldur.

D. **Teoriler kanun olamaz;** çünkü bunlar farklı türdeki düşüncelerdir. Teoriler, kesinliğinden tam olarak emin olunamayan bilimsel düşüncelere dayanır ve doğrulukları kanıtlanamaz. Ancak kanunlar sadece gerçeklere dayanır ve %100 kesindirler.
E. **Teoriler kanun olamaz;** çünkü bunlar farklı türdeki düşüncelerdir. Kanunlar olguları genel olarak **tanımlar**. Teoriler ise bu kanunları **açıklar**. Ancak destekleyici kanıtlarla, hipotezler teorilere veya kanunlara dönüşebilirler.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

7. Bilim adamları, yeni teorileri ya da kanunları geliştirirken, doğa hakkında bazı tahminler yapmaları (bazı şeyleri farzetmeleri) gereklidir (örneğin: maddeler atomlardan oluşur). Bilimin düzenli bir şekilde gelişmesi için bu tahminler doğru olmak zorundadır.

A. **Bilimin gelişmesi için bu tahminler doğru olmalıdır;** çünkü doğru teori ve kanunlar için doğru tahminler gereklidir. Aksi halde bilim adamları, yanlış teori ve kanunları kullanarak çok fazla zamanı ve çabayı boşa harcayacaklardır.
B. **Bilimin gelişmesi için bu tahminler doğru olmalıdır;** aksi halde toplum, yetersiz teknoloji ve tehlikeli kimyasal maddeler gibi ciddi problemlerle karşı karşıya kalır.
C. **Bilimin gelişmesi için bu tahminler doğru olmalıdır;** çünkü bilim adamları çalışmalarını ilerletmeden önce, tahminlerinin doğru olduğunu kanıtlamak için araştırma yaparlar.

D. **Bilimin gelişmesi için tahminlerin doğru olması gerekir düşüncesi duruma bağlıdır.** Bilim bazen ilerleme için doğru varsayımlara ihtiyaç duyar. Ama tarih bazen şunu göstermiştir ki, büyük buluşlar bir teorinin **çürütülmesi** ve onun yanlış tahminlerinin öğrenilmesi ile yapılmıştır.
E. **Bilimin gelişmesi için tahminlerin doğru olup olmaması sorun değildir.** Bilim adamları, projelerine başlamak için doğru ya da yanlış tahminler yapmak zorundadırlar. Tarih göstermiştir ki, büyük buluşlar bir teorinin **çürütülmesi** ve onun yanlış tahminlerinin öğrenilmesi ile yapılmıştır.

F. Bilim adamları varsayımlarda **bulunmazlar.** Onlar, bir fikrin doğru olup olmadığını öğrenmek için araştırırlar. Onun doğru olduğunu varsaymazlar.

G. Anlamadım.
H. Bir seçim yapmak için yeterli bilgiye sahip değilim.
I. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

8. İyi bilimsel teoriler, gözlemleri iyi bir şekilde açıklar. Aynı zamanda iyi teoriler, karmaşık değil basit olurlar.

A. İyi teoriler basit olurlar. Bilimde kullanılacak en iyi **dil** basit, kısa ve doğrudan olandır.

B. Bu ne derecede **derin** açıklamalar yapmak istediğinize bağlıdır. İyi bir teori, birşeyi hem basit hem de karmaşık bir yolla açıklayabilir.
C. Bu, **teoriye** bağlıdır. Bazı iyi teoriler basit, bazıları ise karmaşıktır.
D. İyi teoriler karmaşık olabilir ama kullanılacaklarsa basit, anlaşılabilir bir dile **çevrilebilmelidir**.

E. Teoriler genellikle **karmaşıktır**. Bazı şeyler, eğer birçok ayrıntı içeriyorsa basitleştirilemez.
F. İyi teorilerin çoğu **karmaşıktır**. Eğer dünya daha basit olsaydı, teoriler de basit olabilrlerdi.

G. Anlamadım.
H. Bir seçim yapmak için yeterli bilgiye sahip değilim.
I. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

9. Bilim adamları araştırma yaptıklarında, **bilimsel yöntemi** izledikleri söylenir.

A. **Bilimsel yöntem**, genellikle bilim adamları tarafından dergide ya da kitapta yazılan ve deney yapılırken izlenmesi gereken laboratuvar işlemleri ya da teknikleridir.
B. **Bilimsel yöntem** sonuçların dikkatlice kaydedilmesidir.
C. **Bilimsel yöntem** deney değişkenlerinin, yoruma yer bırakmaksızın dikkatlice kontrol edilmesidir.
D. **Bilimsel yöntem** gerçeklerin, teorilerin ve hipotezlerin etkili şekilde elde edilmesidir.
E. **Bilimsel yöntem** test etmek ve tekrar test etmektir. Bir şeyin doğruluğunu veya yanlışlığını geçerli şekilde kanıtlamaktır.
F. **Bilimsel yöntem** teoriyi kanıtlamak için deney oluşturmaktır.
G. **Bilimsel yöntem** soru sormak, hipotez kurmak, veri toplamak ve sonuca varmaktır.
H. **Bilimsel yöntem** problem çözmede mantıklı ve kabul gören bir yaklaşımdır.
I. **Bilimsel yöntem** bilim adamlarını çalışmalarında yönlendiren bir tutumdur.

J. Bilim adamlarının aslında ne yaptıkları düşünülürse, gerçekte **bilimsel yöntem** diye birşey **yoktur**.

K. Anlamadım.
L. Konu hakkında seçim yapmak için yeterli bilgiye sahip değilim.
M. Seçeneklerin hiçbiri kişisel görüşlerime uymuyor.

10. En iyi bilim adamları, bilimsel yöntemin basamaklarını takip edenlerdir.

A. Bilimsel yöntem geçerli, açık, mantıklı ve kesin sonuçları garanti eder. Bu nedenle, birçok bilim adamı bilimsel yöntemin basamaklarını izleyecektir.
B. Okulda öğrendiklerimize dayanarak, bilimsel yöntem bir çok bilim adamının çalışmasında yararlı olması gerekir.

C. Bilimse yöntem bir çok konuda yararlıdır ama bu yöntemlerin sonuç vereceği garanti değildir. Bundan dolayı başarılı bilim adamları, aynı zamanda orjinalliği ve yaratıcılığı da kullanacaklardır.
D. En iyi bilim adamları, hayal gücü ve yaratıcılık yöntemleri de dahil istenilen sonuçları verebilecek, herhangi biryöntemi kullanan kişilerdir.

E. Bir çok bilimsel keşif, bilimsel yönteme bağlı kalmadan, tesadüfen yapılmıştır.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

11. Bilimsel araştırma sonuçlanana kadar her biri bir sonrakine öncülük eden bir dizi araştırma yapılır.

A. **Bilimsel buluşlar, mantıklı bir dizi araştırmanın sonucudur;** çünkü deneyler (örneğin atom modeline öncülük eden deneyler, ya da kanserle ilgili buluşlar) bir duvarı oluşturan tuğlalar gibidir.

B. **Bilimsel buluşlar, mantıklı bir dizi araştırmanın sonucudur;** çünkü araştırmalar, önceki deneylerin doğruluğunu görmek için sonuçların test edilmesiyle başlar. Yeni bir deney, daha sonra gelecek bilim adamları tarafından test edilecektir.

C. **Genellikle** bilimsel buluşlar mantıklı bir dizi araştırmadan kaynaklanır. Ama bilim tamamen mantıklı değildir. Bu süreçte deneme-yanılma ve şans payı vardır.

D. **Bazı** bilimsel buluşlar tesadüfidir veya bilim adamlarının gerçek beklentilerinin önceden tahmin edilemeyen bir ürünüdür. Fakat buluşların **çoğu** birbiri üzerine inşa edilen bir dizi araştırmanın sonucudur.

E. **Çoğu** bilimsel buluşlar tesadüfidir veya bilim adamlarının gerçek beklentilerinin önceden tahmin edilemeyen bir ürünüdür. **Bazı** buluşlar birbirini izleyen mantıklı bir dizi araştırmanın sonucudur.

F. **Bilimsel buluşlar mantıklı bir dizi araştırmanın sonucunda oluşmaz;** çünkü buluşlar sıklıkla, önceden birbiriyle bağlantılı olmayan bilgi parçalarının bir araya gelmesiyle oluşur.

G. **Bilimsel buluşlar mantıklı bir dizi araştırmanın sonucunda oluşmaz;** çünkü buluşlar, temelde birbiriyle alakasız olan ama beklenmedik bir şekilde birbiriyle ilişkili hale gelen çok çeşitli çalışmaların sonucunda oluşur.

H. Anlamadım.

I. Bir seçim yapmak için yeterli bilgiye sahip değilim.

J. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

12. Bilim adamları, çalışmalarının sonuçlarını bilimsel dergilerde yayınlarlar. Bilim adamları, bir dergi için makale yazdıklarında, raporlarını çok mantıklı ve düzenli şekilde organize ederler. Fakat, bilim adamları aslında çalışmalarını daha az mantıklı bir yolla yaparlar.

A. **Makaleler bilimsel çalışmanın aslından daha mantıklı bir yolla yazılır;** çünkü bilim adamları düzenlenmiş bir planı izlemeden düşünebilir ve çalışabilirler. Sonuç olarak, eğer onların düşüncelerinin ve metodlarının düzenini okursanız, bu fazla karmaşık olabilir. Bu nedenle, bilim adamları diğer bilim adamlarının, sonuçları anlayabilmesi için, makalelerini mantıklı bir yolla yazarlar.

B. **Makaleler bilimsel çalışmanın aslından daha mantıklı bir yolla yazılır;** çünkü bilimsel hipotezler, kişisel görüş veya tahmindir ve sonuç olarak mantıklı değildir. Bu nedenle, bilim adamları diğer bilim adamlarının sonuçları anlayabilmesi için mantıklı bir yolla yazarlar.

C. Bilim adamları genellikle "reçete" vermek istemezler, fakat sonuçlarını dünyaya duyurmak isterler. Bu nedenle, çalışmalarını mantıklı bir biçimde yazarlar ama aslında nasıl yaptıklarını açıklamazlar.

D. Bu, duruma bağlı. Bazen bilimsel buluşlar tesadüfen oluşur ama bazen de buluşlar makalelerin yazıldığı gibi mantıklı ve düzenli şekilde oluşur.

E. **Makaleler asıl çalışmanın nasıl yapıldığını göstererek mantıklı yolla yazılır;** çünkü bilim adamlarının çalışması mantıkla yürütülür; aksi halde bilim ve teknoloji için yararlı olmayacaktır.

F. **Makaleler asıl çalışmanın nasıl yapıldığını göstererek mantıklı yolla yazılır;** bilim adamları basılan raporlarının mantıklı bir şekilde yazımının kolay olması için, çalışmalarını mantıklı bir yolla yaparlar.

G. **Makalelerin mantıklı bir yolla yazılması gerekli değildir.** Onlar çalışmanın yapıldığı şekilde yazılır. Bu, karmaşık veya kolay olabilir.

H. Anlamadım.

I. Bir seçim yapmak için yeterli bilgiye sahip değilim.

J. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

13. Bilim adamlarının çalışmalarında hata yapmamaları gerekir, çünkü bu hatalar bilimin ilerlemesini yavaşlatır.

A. **Hatalar bilimin ilerlemesini yavaşlatır**. Yanıltıcı bilgiler yanlış sonuçlara götürebilir. Eğer bilim adamları sonuçlarındaki hataları anında düzeltmezlerse bilim ilerlemez.

B. **Hatalar bilimin ilerlemesini yavaşlatır**. Yeni teknoloji ve araçlar, doğruluğu artırarak hataları azaltır ve böylece bilim daha hızlı ilerler.

C. **Hatalardan kaçınılamaz;** bu nedenle bilim adamları, bir fikir birliğine ulaşana dek birbirlerini kontrol ederek hataları azaltırlar.

D. **Hatalardan kaçınılamaz;** bazı hatalar bilimin ilerlemesini yavaşlatabilir, ama bazı hatalar yeni veya büyük bir buluşa neden olabilir. Eğer bilim adamları hatalarından birşeyler **öğrenir** ve düzeltirlerse bilim ilerleyecektir.

E. Hatalar genellikle bilimin ilerlemesine **yardım** eder. Bilim, geçmişin hatalarını tespit edip düzelterek ilerler.

F. Anlamadım.

G. Bir seçim yapmak için yeterli bilgiye sahip değilim.

H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

14. Kesin bilgilere dayanarak varsayımlar yaparken bile, bilim adamları ve mühendisler bize sadece neyin muhtemelen olabileceğini söyleyebilirler. Kesin olarak ne olacağını söyleyemezler.

A. **Varsayımlar asla kesin değildir;** çünkü daima sonucu etkileyecek önceden tahmin edilemeyen olaylar ve hata olasılığı vardır. Hiçkimse geleceği kesin olarak tahmin edemez.
B. **Varsayımlar asla kesin değildir;** çünkü yeni buluşlar yapıldıkça, kesin bilgi değişir ve bu nedenle de varsayımlar daima değişecektir.
C. **Varsayımlar asla kesin değildir;** çünkü varsayım gerçeğin belirtilmesi değildir. Varsayım iyi yapılmış bir tahmindir.
D. **Varsayımlar asla kesin değildir;** çünkü bilim adamları asla tüm gerçeklere sahip değillerdir. Bazı bilgiler daima eksiktir.

E. **Duruma bağlıdır.** Varsayımlar ancak doğru ve yeterli bilginin olması halinde kesindir.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

15. Eğer bilim adamları, asbestle çalışan insanların akciğer kanserine yakalanma ihtimalinin ortalama bir insanınkinin iki misli olduğunu bulurlarsa, bu asbestin akciğer kanserine sebep olduğu anlamına gelmelidir.

A. **Bu gerçekler açık şekilde asbestin akciğer kanserine sebep olduğunu kanıtlar.** Eğer asbest işçilerinin, akciğer kanserine yakalanma şansı daha fazlaysa, bu durumda kanserin sebebi asbesttir.

B. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir;** çünkü akciğer kanserine asbestin mi veya başka bir maddenin mi yol açtığını bulmak için **daha fazla araştırmaya** ihtiyaç vardır.

C. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir;** çünkü asbest **başka şeylerle birlikte** veya dolaylı olarak buna yol açabilir (örneğin akciğer kanserine yakalanmaya sebep olan diğer şeylere karşı direnci zayıflatabilir).

D. **Bu gerçekler asbestin akciğer kanserine sebep olduğu anlamına gelmeyebilir;** çünkü eğer asbest kanser yapsaydı, **tüm** asbest işçileri akciğer kanserine yakalanmış olurdu.

E. Asbest akciğer kanserinin nedeni **olamaz** çünkü asbestle çalışmayan bir çok insan da akciğer kanserine yakalanmaktadır.

F. Anlamadım.

G. Bir seçim yapmak için yeterli bilgiye sahip değilim.

H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

16. Bilim doğal dünyanın doğaüstü varlıklar tarafından değiştirilemeyeceği (örneğin tanrı) varsayımına dayanır.

A. **Bilim adamları, doğaüstü bir varlığın doğal dünyayı değiştirmeyeceğini varsayar;** çünkü doğaüstü, bilimsel olarak kanıtlanamaz. Bilimin dışındaki diğer bakış açıları, doğaüstü bir varlığın doğal dünyayı değiştirebileceğini varsayar.
B. **Bilim adamları, doğaüstü bir varlığın doğal dünyayı değiştirmeyeceğini varsayar;** çünkü şayet doğaüstü bir varlık varolsaydı, bilimsel gerçekler bir göz kırpışıyla değişirdi. Ancak bilim adamları sürekli tutarlı sonuçlara ulaşırlar.

C. **Bu, duruma bağlıdır**. Bilim adamlarının doğaüstü bir varlık hakkındaki varsayımları kişisel olarak değişmektedir.
D. **Her şey mümkündür**. Bilim doğa hakkındaki her şeyi bilmez. Bundan dolayı, bilim doğaüstü varlıkların doğal dünyayı değiştirebileceği olasılığına karşı açık görüşlü olmalıdır.

E. **Bilim doğaüstünü de araştırabilir ve belki açıklayabilir.** Bundan dolayı, bilim doğaüstü varlıkların olduğunu kabuledebilir.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

17. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın "keşfettiğini" farzedelim. Bazı insanlar bilim adamlarının bilimsel **KANUNLARI** "keşfettiğini", bazıları ise icat ettiklerini" düşünürler. Siz ne dersiniz?

A. **Bilim adamları bilimsel kanunları keşfederler;** çünkü kanunlar doğadadır ve bilim adamları sadece onları bulmak zorundadır.
B. **Bilim adamları bilimsel kanunları keşfederler;** çünkü kanunlar deneysel **gerçeklere** dayanır.
C. **Bilim adamları bilimsel kanunları keşfederler;** fakat bilim adamları bu kanunları bulmak için **yöntemleri** yaratırlar.

D. Bazı bilim adamları, bir kanunu şans eseri bulur, yani keşfeder. Fakat diğer bilim adamları kanunları önceden bildikleri gerçeklere dayanarak icat ederler.
E. **Bilim adamları bilimsel kanunları icat ederler;** çünkü bilim adamları buldukları deneysel gerçekleri yorumlar. Bilim adamları doğanın yaptıklarını değil, doğanın yaptıklarını **tanımlayan** kanunları icat ederler.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

18. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın keşfettiğini farzedelim. Bazı insanlar bilim adamlarının bilimsel **HİPOTEZLERİ** "keşfettiğini", bazıları ise "icat ettiklerini" düşünürler. Siz ne dersiniz?

A. **Bilim adamları bir hipotezi keşfederler;** çünkü düşünce her zaman doğada, açığa çıkartılmayı bekler.
B. **Bilim adamları bir hipotezi keşfederler;** çünkü hipotez deneysel **gerçeklere** dayanır.
C. **Bilim adamları bir hipotezi keşfederler;** fakat bilim adamları bir hipotezi bulmak için **yöntemleri** icat ederler.

D. Bazı bilim adamları, bir hipotezi şans eseri bulur, yani keşfederler. Ancak diğer bilim adamları hipotezi önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim adamları bir hipotezi icat ederler;** çünkü bir hipotez, bilim adamlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır.
F. **Bilim adamları bir hipotezi icat ederler;** çünkü hipotezler zihinden gelir, onları biz oluştururuz.

G. Anlamadım.
H. Bir seçim yapmak için yeterli bilgiye sahip değilim.
I. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

19. Bir sanatçı bir heykeli "icat ederken", bir altın madencisinin de altın keşfettiğini farzedelim. Bazı insanlar bilim adamlarının bilimsel **TEORİLERİ** "keşfettiklerini", bazıları ise "icat ettiklerini" düşünürler. Siz ne dersiniz?

A. **Bilim adamları bir teoriyi keşfederler;** çünkü düşünce her zaman doğada açığa çıkartılmayı bekler.
B. **Bilim adamları bir teoriyi keşfederler;** çünkü bir teori deneysel **gerçeklere** dayanır.
C. **Bilim adamları bir teoriyi keşfederler;** fakat bilim adamları bu teorileri bulmak için **yöntemleri** icat ederler.

D. Bazı bilim adamları, bir teoriyi şans eseri bulur, yani keşfeder. Ancak diğer bilim adamları, teoriyi önceden bildikleri gerçeklere dayanarak icat ederler.

E. **Bilim adamları bir teoriyi icat ederler;** çünkü bir teori, bilim adamlarının keşfetmiş olduğu deneysel gerçeklerin yorumlanmasıdır.
F. **Bilim adamları bir teoriyi icat ederler;** çünkü teoriler zihinden gelir, onları biz oluştururuz.

G. Anlamadım.
H. Bir seçim yapmak için yeterli bilgiye sahip değilim.
I. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

20. Farklı alanlardaki bilim adamları, aynı şeye çok farklı açılardan bakarlar (örneğin, H^+ kimyagerlerin asit oranını, fizikçilerin protonları düşünmelerine sebep olur). Bu, farklı alanlarda çalışan bilim adamlarının birbirlerinin çalışmalarını anlamalarını zorlaştırır.

A. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları zordur;** çünkü bilimsel düşünceler bilim adamlarının **bakış açısına** veya onların alışkanlıklarına bağlıdır.
B. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları zordur;** çünkü bilim adamları kendi alanları ile kesişen diğer alanların dilini anlamak için çaba sarfetmelidirler.

C. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır;** çünkü bilim adamları zekidir ve bu nedenle diğer alanların dillerini ve bakış açılarını öğrenmenin yollarını bulabilirler.
D. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır;** çünkü bilim adamlarının aynı anda değişik alanlarda çalışmış olmaları muhtemeldir.
E. **Farklı alanlardaki bilim adamlarının birbirlerini anlamaları oldukça kolaydır;** çünkü farklı alanlardaki bilimsel düşünceler kesişir. Gerçekler bilimsel alan ne olursa olsun gerçektir.

F. Anlamadım.
G. Bir seçim yapmak için yeterli bilgiye sahip değilim.
H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

21. Farklı alanlardaki bilim adamları aynı şeye çok farklı açılardan bakarlar (örneğin, H^+ kimyagerlerin asit oranını, fizikçilerin protonları düşünmelerine sebep olur). Bunun anlamı, bir bilimsel düşüncenin bilim adamının çalıştığı alana bağlı olarak farklı anlamlara sahip olduğudur.

A. **Bilimsel bir düşünce farklı alanlarda farklı anlamlara gelecektir;** çünkü bilimsel düşünceler **bir alanda**, diğer bir alana göre farklı yorumlanabilir.

B. **Bilimsel bir düşünce farklı alanlarda farklı anlamlara gelecektir;** çünkü bilimsel düşünceler bilim adamının **kişisel** görüşlerine veya önceki bilgilerine bağlı olarak farklı şekilde yorumlanabilir.

C. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** çünkü bilim adamının bakış açısı ne olursa olsun, düşünce yinede doğadaki **aynı gerçekleri ifade eder**.

D. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** çünkü tüm bilimler birbirleriyle **yakın ilişki** içindedir.

E. **Bilimsel bir düşünce tüm alanlarda aynı anlama gelecektir;** farklı alanlardaki insanların birbirleriyle iletişim kurmaları için bu gereklidir. Bilim adamları aynı anlamları kullanmak için **anlaşmalıdırlar**.

F. Anlamadım.

G. Bir seçim yapmak için yeterli bilgiye sahip değilim.

H. Seçeneklerin hiçbirisi kişisel görüşlerimi yansıtmıyor.

APPENDIX B

GÖRÜŞME SORULARI

1- Sizce bilim nedir? Bilimi (ya da fizik, kimya, biyoloji gibi bilimsel alanları) din ve felsefe gibi disiplinlerden ayıran nedir? Açıklayınız.

2- Deney sizce nedir? Bilimsel bir bilginin gelişmesi için deney gereklimidir? Görüşlerinizi örneklerle açıklayınız.

3- Bilim adamlarınca takip edilen bilimsel bir yöntem varmıdır?

4- Bilimsel modeller (örneğin atom ve DNA modeli) ve bilimsel sınıflandırmalar (örneğin periyodik cetvel ve canlıların sınıflandırılması) gerçeğin kopyalarımıdır? Açıklayınız.

5- Bilimsel teoriler ve bilimsel kanunlar arasında bir fark varmıdır? Açıklayınız.

6- Bilimsel bilgiler ve teoriler (örneğin atom teorisi, evrim teorisi) zamanla değişirler mi?

- Eğer bilimsel teorilerin değişeceğine inanıyorsanız, niçin olduğunu açıklayınız. Sizce bu durumda niçin bilimsel teorileri öğreniyoruz. Görüşlerinizi örneklerle açıklayınız.
- Eğer bilimsel teorilerin değişmeyeceğine inanıyorsanız, niçin olduğunu açıklayınız. Görüşlerinizi örneklerle açıklayınız.

7- Bilim adamları bazen aynı dataları kullanarak farklı hipotezlere ve farklı teorilere ulaşabilirler. Sizce bunun nedeni nedir?

8- Bilim oluşturulduğu toplumun sosyal ve kültürel değerlerinden etkilenir mi, yoksa evrenselmidir? (yani bilimin oluşturulduğu toplumla bir ilişkisi yokmudur?) Niçin ve nasıl olduğunu örneklerle açıklayınız.

9- Biyoloji, fizik ve kimyanın kavramları, kanunları ve teorileri birbirleriyle ilişkili midir?

10- Bilimin kesinliği hakkında ne söyleyebiliriz?