THE EFFECT OF HISTORY OF SCIENCE INSTRUCTION ON ELEMENTARY STUDENTS' SCIENTIFIC LITERACY

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ABSTRACT

THE EFFECT OF HISTORY OF SCIENCE INSTRUCTION ON ELEMENTARY STUDENTS' SCIENTIFIC LITERACY

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The purpose of this study is to investigate the effectiveness of history of science instruction on elementary students' scientific literacy. Specifically, the effectiveness of history of science instruction over curriculum-oriented instruction was examined in terms of four central components of scientific literacy, which are science process skills, understanding of human circulatory system concepts, attitudes toward science, and nature of science views.

A total of 95 sixth-grade students from four classes participated to the study. Among them, two classes were randomly assigned as experimental group and other two as comparison group. Experimental group students learned the circulatory system topic through the history of circulatory system, integrated into the curriculum-oriented instruction. The comparison group was engaged in curriculum-oriented instruction, but without integration of history of circulatory system. Science Process Skills Test, Circulatory System Concepts Test, Test of Science Related Attitudes, and Views on Nature of Science Elementary School Version were administered to the participants as pretest, posttest, and follow-up test.

The results of this study showed that two instructions did not give an advantage over each other in terms of science process skills. On the other hand, history of science instruction was found to be more effective than curriculum oriented instruction in terms of retaining circulatory system concepts, promoting students' favorable attitudes toward science, and improving nature of science views. Therefore, it is recommended that curriculum developers should incorporate history of science into science curriculum implemented in Turkey, and science teachers should use it in their classrooms more actively.

Keywords: Scientific Literacy, Circulatory System, History of Science, Science Process Skills, Nature of Science

ÖZ

BİLİM TARİHİ EĞİTİMİNİN ORTAOKUL ÖĞRENCİLERİNİN FEN OKURYAZARLIĞINA ETKİSİ

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Bu çalışmanın amacı, bilim tarihi eğitiminin ortaokul öğrencilerinin fen okuryazarlığı üzerindeki etkisini araştırmaktadır. Spesifik olarak, bilim tarihi eğitiminin müfredat tabanlı eğitime göre etkisi, fen okur-yazarlığının dört temel bileşenleri olan bilimsel süreç becerileri, dolaşım sistemi kavramlarının anlaşılması, fene karşı tutum ve bilimin doğası görüşleri açısından incelenmiştir.

Bu çalışmaya dört ayrı sınıftan 95 altıncı sınıf öğrencisi katılmıştır. Bunlardan iki sınıf deney grubu ve diğer iki sınıf da karşılaştırma grubu olarak rastgele atanmıştır. Deney grubunda dolaşım sistemi tarihi müfredata entegre edilmiş ve öğrenciler dolaşım sistemi konusunu bu yöntemle öğrenmiştir. Karşılaştırma grubu ise dolaşım sistemi tarihi olmadan müfredat tabanlı eğitimle aynı konuyu öğrenmiştir. İki gruptaki öğrencilere de Bilimsel Süreç Becerileri Testi, Dolaşım Sistemi Kavram Testi, Fen Tutum Testi ve Bilimin Doğası Ölçeği: FORM-E ön test, son test ve takip testi olarak uygulanmıştır.

Bu çalışmanın sonucu bilimsel süreç becerileri açısından iki öğretimin birbirlerine göre bir fark ortaya çıkarmadığını göstermiştir. Diğer taraftan, dolaşım sistemi kavramlarını akılda tutma, fene karşı olumlu tutum geliştirme ve bilimin doğası hakkında daha yeterli görüş ortaya koyma açısından bilim tarihi eğitiminin müfredat tabanlı eğitime göre daha başarılı olduğu ortaya konmuştur.

Bu çalışmada ortaya konan sonuca dayanarak, müfredat geliştiricilere bilimin tarihini Türkiye'de uygulanan fen ve teknoloji öğretim programına entegre etmesi ve fen bilgisi öğretmenlerine de sınıflarında bilim tarihini daha aktif kullanması gerektiği tavsiye edilmektedir.

Anahtar Kelimeler: Fen Okuryazarlığı, Dolaşım Sistemi, Bilim Tarihi, Bilimsel Süreç Becerileri, Bilimin Doğası

To My Family

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LIST OF ABBREVIATIONS

AAAS: American Association for the Advancement of Science

ANOVA: Analysis of Variance

HOS: History of Science

MANOVA: Multivariate Analysis of Variance

MoNE: Ministry of National Education

NOS: Nature of Science

NRC: National Research Council

OECD: The Organization for Economic Cooperation and Development

PISA: The Programme for International Student Assessment

SL: Scientific Literacy

SPS: Science Process Skills

SPST: Science Process Skills Test

SSI: Socio-scientific Issues

TOSRA: Test of Science-Related Attitudes

VNOS-E: Views of Nature of Science Elementary School Version

CHAPTER I

INTRODUCTION

Today, it is widely accepted among science educators that efforts invested in the improvement of science education are mainly for developing scientifically literate individuals, making science meaningful for all people, not for specific groups (Bybee, 1997; Feinstein, 2011; Millar, 2006; Roberts, 2007). Indeed, Rutherford and Ahlgren (1990) stated that "our fundamental premise is that schools do not need to be asked to teach more and more content, but rather focus on what is essential to scientific literacy and to teach it more effectively" (p. ix) because scientific literacy (SL) is crucial for today's world societies in which science and technology changes very rapidly. Thus, countries should be prepared to adapt themselves to the changes in science and technology in order to be successful and developed in the global world. To be able to achieve this end, focus should be given to the individuals of the societies: If the society is educated in a way that it prepares individuals to meet today's technology and science requirements, the country can be able to maintain the functional role on the global scale straightforwardly. Thus the crucial point in national "adaptation" is to educate individuals as much scientifically literate as possible because scientifically literate individuals understand key scientific concepts and the relation between science-technology-society easily (Abd-El-Khalick & BouJaoude, 1997). As a result, development of scientifically literate individuals is recognized as one of the major goals of science education by many science educators, researchers, and governments including Turkey (BouJaoude, 2002; Milli Egitim Bakanligi (Ministry of National Education) [MoNE], 2006; Zembylas, 2002) and many efforts were attempted to improve scientific literacy (Project 2000+, 1993; Project 2061, 1990; Science Literacy Project, 1999, 2005). Among them, a project called as Project 2061, which was carried out in U.S., was one of the most central ones in the history of scientific literacy. Science for All Americans (American Association for the Advancement of Science [AAAS], 1989) and Benchmarks for Science Literacy (AAAS, 1993) were the products of this project. *Science for All Americans* covered four themes. These are nature of science, mathematics, and technology; the impact of technology on science and mathematics; the effect of history of great scientific episodes on people about world works; the practice of thought needed for scientific literacy. Similarly, *Benchmarks for Science Literacy* specify the levels students are expected to reach at the end of 2nd, 5th, 8th, and 12th grades, in terms of what they know and be able to do in three domains, namely, science, technology, and mathematics to reasonably progress through scientific literacy. Moreover, *The National Science Education Standards* (National Research Council [NRC], 1996) contributed to the reforms in science education by setting the standards for achieving scientific literacy. This document organized standards under six categories. These are standards for: science teaching, professional development for teachers of science, assessment in science education, science content, and science education systems. Recently National Research Council released the *Next Generation Science Standards* to “provide a more coherent progression aimed at overall scientific literacy with instruction focused on a smaller set of ideas and an eye on what the student should have already learned and what they will learn at the next level” (NRC, 2013, p.3). Overall, these reform movements tried to improve science education by placing scientific literacy as their ultimate goal.

In addition to international reform movements in science education, the Ministry of National Education (MoNE) in Turkey has undergone changes in 2004 and released the new science and technology curriculum in 2006. The vision of the curriculum is to educate all students as scientifically literate regardless of individual differences (MoNE, 2006). In science and technology curriculum, scientific literacy was described as a collection of skills, attitudes, values, understanding and knowledge in order to make inquiries and investigations, think critically, solve daily life problems, make informed decisions, and become a life-long learner. Seven dimensions for scientific literacy were suggested in the curriculum. These are, nature of science and technology, key science concepts, science process skills, science-technology-society-environment interaction, scientific and technical psychomotor skills, scientific values, and attitudes toward science (MoNE, 2006).

Apart from the seven aspects emphasized in national science curriculum in Turkey, different aspects of scientific literacy were examined in the relevant literature. For example, in Science for All Americans (AAAS, 1998) it was emphasized that scientifically literate individuals should understand science concepts, possess science process skills and comprehend the interaction between science, technology, and society. Similarly, The Organization for Economic Cooperation and Development [OECD] (2003) underlined the ability of using scientific knowledge and making decisions in defining scientific literacy. Moreover, Abd-El-Khalick and BouJaoude (1997) emphasized three aspects of scientific literacy, namely understanding science concepts and processes of science, being aware of the relation between science-technology-society, and developing nature of science understanding. While defining scientific literacy, Matthews (1994) focused on learning of basic scientific concepts and connecting science to daily life. The Programme for International Student Assessment (PISA) of the OECD (2006) extended its definition of scientific literacy by including attitudes toward science. It was emphasized that:

> A student's ability to carry out the scientific competencies involves both knowledge of science and an understanding of the characteristics of science as a way of acquiring knowledge (i.e. knowledge about science). The definition also recognizes that the disposition to carry out these competencies depends upon an individual's attitudes towards science and a willingness to engage in science-related issues (p. 23).

Additionally Chin (2005) described attitudes toward science as a vital domain of scientific literacy with other three domains which are "science content, the interaction between science-technology-society and the nature of science" (p. 1549). Bybee and McCrae (2011) also discussed that scientific knowledge and attitudes toward science are the central contributors to the scientific literacy.

In the current study, based on the national science curriculum and abovementioned literature, four core aspects of scientific literacy were identified, namely science process skills, science content knowledge, attitudes toward science, and nature of science.

The first aspect of SL is science process skills. Lederman (2009) stated that science process skills are closely related to the scientific inquiry. Students should develop an understanding that scientific knowledge is produced as a result of scientific inquiry processes (Bybee et al., 1991) through constructing and criticizing ideas. The National Committee on Science Education Standards (1996) stressed science as a way of knowing about the natural world. Science education should help students improve an understanding of what science is about and how scientific knowledge is generated (AAAS, 1989; Murcia, 2009; Mutonyi, Nielsen, & Nashon, 2007; NRC, 1992; 1996; Shen, 1975). Similarly Rezba, Sprague, McDonnough, and Matkins (2007) stated that the goals for science education should emphasize science as way of thinking and investigating. The authors added that ways of thinking in science refer to the process skills. These skills were based on the ability to acquire, interpret and act upon evidence (OECD, 2006, p. 12). Rezba et al. (2007) mentioned about basic and integrated science process skills. Basic science process skills are the ones used to explore natural world. These skills include observing, predicting, inferring, classifying, measuring, and communicating (Rezba et al., 2007). The integrated process skills are the skills that lead to scientific investigations and known as identifying variables, constructing hypothesis, analyzing investigations, tabulating and graphing data, defining variables, designing investigations, and experimenting (Rezba et al., 2007). Rezba and colleagues emphasized that integrated process skills are based on basic process skills and acquisition of the integrated process skills enable students to test their ideas through planning investigations. Similarly, Bailer, Ramig, and Ramsey (1995) stated that "Students skilled in science processes will be able to conduct investigations on a topic of their own choosing with minimal teacher guidance" (p.5). Therefore teachers should help students improve these skills in classrooms.

The second fundamental aspect of scientific literacy is to understand basic science concepts. Martin, Sexton, and Franklin (2005) identified three essential characteristics of science as attitudes, skills, and knowledge. They stated that knowledge includes what scientists explore and make public. Learning this knowledge is one of the major goals of science curricula. Individuals should have a basic understanding of scientific concepts and theories to become scientifically literate (AAAS, 1989; NRC, 1996; OECD, 2003).

The third aspect of SL is attitudes toward science. Koballa and Crawley (1985) defined attitudes toward science as "a general and enduring positive or negative feeling about science" (p. 223). Individuals' attitudes may have a fundamental role in their interest in science and scientific inquiry. OECD (2006) emphasized that one of the goals of science education is to cultivate students' attitudes toward science which, in turn, increase their participation in science and use of science for personal and societal benefits. To achieve this goal, researchers focused on different instructional strategies that favor students' attitudes toward science such as hands-on laboratory program (Freedman, 1997), creative drama (Hendrix, Eick, Shannon, 2012), argumentation-based instruction (Cakir, 2011) as well as history of science instruction (Kubli, 1999).

The last core aspect of SL is nature of science (NOS). NOS is commonly defined as "values and assumptions inherent to scientific knowledge" (Lederman & Zeidler, 1986, p. 1) and refers to science as a way of knowing (Lederman, 1992). Nature of science has been a perennial goal of science education and emphasized in many reform documents and scholarly papers (AAAS, 1989, 1993; Bell, Matkins & Gansneder, 2011; Lederman, 1992; NRC, 1996) to educate students as scientifically literate. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) introduced the aspects of NOS which are accessible to K-12 students and received common acceptance among researchers. These are "scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of universal recipe like method for doing science, and the function of and relationships between scientific theories and laws" (p. 499). Having an adequate understanding of these aspects is essential for individuals to be scientifically literate. Therefore, students should be engaged in practices in science classrooms to develop NOS understanding.

A variety of instructional strategies were implemented to improve aforementioned aspects of the scientific literacy. For example, in order to develop science process skills, activity-based instruction (Turpin, 2000); inquiry-based instruction (Yager & Akcay, 2010); guided-inquiry (Koksal & Berberoglu, 2014; Yildirim, 2012); and creative-drama based instruction (Taskin-Can, 2013) were utilized in classrooms. Moreover, a number of instructional strategies including argumentation-based instruction (Zohar & Nemet, 2002); problem-based learning (Sungur, Tekkaya, & Geban, 2006); socioscientific-based instruction (Klosterman & Sadler, 2010); case-based instruction (Boz & Uzuntiryaki, 2008) were implemented to foster learning of science concepts. Similarly, argumentation-based intervention (Cakir, 2011); creative drama (Hendrix, Eick, & Shannon, 2012); guided-inquiry instruction (Koksal & Berberoglu, 2014); hands-on laboratory instruction (Freedman, 1997) were utilized to develop positive attitudes toward science. Finally, instructional strategies such as explicit-reflective activity based instruction (Akerson, Abd-El-Khalick, & Lederman, 2000; Colak, 2009; Khishfe, 2008); experiential science program (Jelinek, 1998); laboratory activities (McComas, 1993); generic activities (Lederman & Abd-El-Khalick, 1998) were used for developing students' NOS views. In addition to the incomplete list of strategies presented above, history of science (HOS) was recommended as an alternative strategy for achieving scientific literacy (e.g. Rutherford & Ahlgren, 1990).

The reforms in science education underlined the need for the inclusion of history of science into science classrooms (NRC, 1996). Kuhn (1970) argued the importance of the progress of scientific knowledge throughout history and recommended that history of science should be a part of science curricula. The need to integrate HOS into science curricula was also highlighted in Project 2061 (AAAS, 1989). History of science has numerous benefits for science education including teaching science content, creating authentic learning environments, developing reasoning and thinking skills, and cultivating interest and attitude in science through humanizing it (Matthews, 1994).Therefore teachers should benefit from history of science in their classrooms.

1.1 Research Problem

The main focus of this study was to investigate the comparative effectiveness of the HOS instruction and curriculum-oriented instruction on grade six students' scientific literacy. In the present study, scientific literacy was examined in terms of students' science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science views.

Accordingly, one of the purposes of the current study was to examine the effect of HOS instruction on students' science process skills. As one of the aspects of scientific literacy, students should develop abilities to conduct scientific investigations. Through history of science, they become familiar with how ancient scientists conducted experiments and investigations; as a result of these they become informed about how scientific knowledge is produced. Matthews (1994) emphasized that historical approach to science instruction can improve students' comprehension of scientific methods and join their own thinking with the development of ideas in the past. Thus, in the present study, it is expected that, in terms of science process skills, students receiving HOS instruction will be better than the students receiving curriculum-oriented instruction.

The second purpose was to investigate the effectiveness of HOS instruction on students' understanding of human circulatory system concepts. Ernst Mayr (1982) provided a good argument for the history of science instruction to understand the scientific concepts. Mayr (1982) argued that:

> …the study of the history of a field is the best way of acquiring an understanding of its concepts. Only by going over the hard way by which these concepts were worked out -by learning all the earlier wrong assumptions that had to be refuted one by one, in other words by learning all past mistakes- can one hope to acquire a really thorough and sound understanding. In science one learns not only by one's own mistakes but by the history of the mistakes of others (p. 20)

Mayr (1982) emphasized the role of wrong assumptions and mistakes made in the past in understanding the scientific concepts. Matthews (1994) also highlighted the history as a way to comprehend scientific concepts better due to its role of making scientific concepts less abstract and attractive. The specific topic studied in this study was circulatory system and it mostly involves abstract concepts. Students cannot directly observe the circulatory system concepts such as pulmonary circulation and they get stacked in understanding them. HOS instruction can enable students to figure out how these concepts evolved in the past. Students can realize the wrong hypothesis formulated by ancient scientists and this led to the new investigations and the modern circulatory system was achieved. Thus, in the present study, it is expected that students receiving HOS instruction have a better understanding on circulatory system concepts than the students receiving curriculum-oriented instruction.

The third purpose of this study was to explore the influence of HOS instruction on students' attitudes toward science. Science education aims to develop positive attitudes toward science and history of science was considered to serve for this goal (Russell, 1981). Matthews (1994) recommended that "History, by examining the life and times of individual scientists, humanizes the subject matter of science, making it less abstract and more engaging for students" (p. 50). Thus, it is suggested that science is humanized through HOS instruction (Monk, & Osborne, 1997) and this may result in increased students' attitudes in science. As Monk and Osborne (1997) emphasized, HOS can be integrated as an instructional strategy to engage students in science classrooms to improve their science learning and attitudes toward science. Lin, Cheng, and Chung (2010) reported that history of science instruction promote attitudes toward science. However, Teixeira, Greca, and Freire (2012) critically examined four studies, which used history of science as instructional tool, to check its effectiveness on attitudes toward science. They pointed out that two of them had evidence to improve attitudes toward science, but other two could not provide clear evidence. They stated that in the literature there is stronger divergence in the HOS studies regarding the change in students' attitudes towards science. Thus, there is a need for further studies to clearly establish the link between HOS instruction and attitudes toward science. In the present study, it is expected that students receiving HOS instruction have more favorable attitudes than the students receiving curriculum-oriented instruction.

Last, this study focused on the effect of HOS instruction on students' understanding of NOS. Matthews (1994) clearly stated that "History is necessary to understand the nature of science" (p. 50). NRC (1996) also explained the role of history in developing NOS views as "The historical perspectives of scientific explanations demonstrates how scientific knowledge changes by evolving over time, almost always building on earlier knowledge" (p. 204). The National Science Education Standards (NRC, 1996) also referred to the history of science for understanding the nature of science. It was stated that:

> In learning science, students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history of science in school science programs, to clarify different aspects of scientific inquiry, the human aspects of science, and the role science has played in the development of various cultures (p. 107).

History of science can be a good context in showing that science has tentative, empirical, subjective, creative, and inferential components. Moreover, students can follow how different cultures affected the scientific knowledge throughout history. In this study, circulatory system concepts were introduced as how they were conceptualized in the past. For example Galen's explanations for the blood circulation were introduced and then how scientific investigations and experiments carried out by other scientists led to the change in those explanations. As a result, students may become aware of the fact that scientific explanations may change by conducting new investigations and providing empirical evidence. Thus, in the present study, it is expected that students receiving HOS instruction have more sophisticated nature of science understanding than the students receiving curriculum-oriented instruction.

1.2 Hypothesis

Overall, in the current study, it is hypothesized that the HOS instruction will improve Grade six students' science process skills, their understanding of human circulatory system concepts, attitudes toward science, and nature of science views. That is, students getting HOS instruction will have advanced science process skills, a better understanding of human circulatory system concepts, more positive attitudes toward science, and more adequate understanding of nature of science than students getting curriculum-oriented instruction.

1.3 Research Questions

The main research question and sub-questions were stated below.

Main Question

To what extent HOS instruction and curriculum-oriented instruction create different profiles on the collective dependent variables of science process skills, understanding of human circulatory system concepts, attitudes toward science, and NOS views across three testing conditions (pre-instruction, post-instruction and follow-up)?

Sub-questions

1) To what extent HOS instruction is more effective than curriculum-oriented instruction in developing students' science process skills across three testing conditions?
   i. What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to science process skills at pre-instruction, post-instruction, and follow-up measurements?
   ii. How do each group students' science process skills change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?
2) To what extent HOS instruction is more effective than curriculum-oriented instruction in developing students' understanding of circulatory system concepts across three testing conditions?
   i. What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to understanding of circulatory system concepts at pre-instruction, post-instruction, and follow-up measurements?
   ii. How do each group students' understanding of human circulatory system concepts change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?
3) To what extent HOS instruction is more effective than curriculum-oriented instruction in developing students' attitudes toward science across three testing conditions?

i. What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to attitudes toward science at pre-instruction, post-instruction, and follow-up measurements?

ii. How do each group students' attitudes toward science change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?

4) To what extent HOS instruction is more effective than curriculum-oriented instruction in developing students' NOS views regarding empirical, tentative, subjective, creative and imaginative, and inferential aspects across three testing conditions?

i. What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to views on targeted NOS aspects at pre-instruction, post-instruction, and follow-up measurements?

ii. How do each group students' views on targeted NOS aspects change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?

1.4 Definition of Variables

Attitudes toward science.

Koballa and Crawley (1985) defined attitudes toward science as "a positive or negative feeling about science" (p.223). In this study, students' attitudes toward science were measured by Test of Science-Related Attitudes (TOSRA) developed by Fraser (1978).

Science process skills.

These skills “represent the rational and logical thinking skills used in science” (Burns, Okey, & Wise, 1985, p. 169). In this study, students’ science process skills were measured by Science Process Skills Test (SPST) developed by (Burns et al., 1985).

Nature of science.

Lederman (1992) defined nature of science as the “epistemology of science, science as a way of knowing, or the values and beliefs of scientific knowledge and its development” (p. 331). In this study nature of science was measured by using the Views of Nature of Science Elementary School Version (VNOS-E) developed by Lederman and Ko (2004).

Curriculum-oriented instruction.

Curriculum-oriented instruction was based on the national science curriculum approach. Ministry of National Education has redesigned the curriculum for elementary school classes in 2004. The vision of the new science curriculum is to develop scientifically literate citizens for future (MoNE, 2004). Berberoglu, Arikan, Demirtasli, Is-Guzel, and Ozgen-Tuncer (2009) pointed out that the current science curriculum was designed as student centered and higher order thinking skills were aimed to develop. The previous curriculum were based on behavioral approach and with the current curriculum it is claimed that behavioral approach is not suitable any more. The current curriculum includes less content but it aims to make students active in class and to improve their higher order thinking skills. The role of students and teachers has also changed. Students try to construct knowledge by themselves and the teachers guide them in this process. Besides emphasizing the higher order thinking skills, the current curriculum has a spiral structure that is thinking skills are emphasized through different grade levels and activities and examples guide teachers in science teaching. Therefore the curriculum-oriented instruction included constructivist teaching methods as emphasized in the national science curriculum (MEB, 2004). In the curriculum, each topic was designed based on 5E instructional model. Each "E" stands for a stage of sequence in teaching and learning, namely Engage, Explore, Explain, Elaboration and Evaluate.

History of science instruction.

The experimental group learned the circulatory system concepts through the history of circulatory system integrated into the curriculum-oriented instruction. There were activities in the curriculum and those activities were modified by integrating the history of circulatory systems. The experimental group in this study carried out the modified activities with HOS. Historical materials such as early scientists' view of circulatory system; the studies of ancient societies; and the historical affairs were introduced to the experimental group.

1.5 Significance of the Study

Scientific literacy has been defined one of the major goals of science education in both international and national reform movements. National Science Education Standards provided clear argument about the importance of scientific literacy.

> Scientific literacy enables people to use scientific principles and processes in making personal decisions and to participate in discussions of scientific issues that affect society. A sound grounding in science strengthens many of the skills that people use every day, like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning (NRC, 1996, p. 9).

Being aware of this, researchers were interested in improving students' scientific literacy in science classrooms (e.g. Biernacka, 2006; Cavagnetto, 2010; Khasnabis, 2008; Kolstø, 2001; Palincsar, Anderson, & David, 1993). This experimental study will provide an opportunity to find out if history of science instruction is an effective way to develop the core aspects of scientific literacy among sixth grade students.

This study also provides teachers, educators and curriculum developers with ideas for inclusion of history of science into science education. Teachers can use the historical materials developed in human circulatory system in their classrooms to help students improve certain elements of scientific literacy which are science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science. Laugksch (2000) expressed that SL can be considered as multidimensional including science concepts and ideas, and the nature of science. In the same vein, history of science was seen as a means to help students to understand science concepts and nature of science better (Matthews, 1994). The science is evolutionary in nature. Krebs (1999) stated that science is unique within other disciplines since it has the capacity to develop in time through new theories and it is important that students should realize how scientific knowledge is developed in time. Integrating historical materials about science content into the curriculum may engage students in development of science content and enhance their NOS views. Students' attitudes toward science may also affect their scientific literacy. Wieder (2006) emphasized that teaching science from a historical perspective may serve to increase student' interest by humanizing the scientific process. Integrating history of science into the science curriculum may help students to develop positive attitudes toward science. Moreover, students can develop science process skills by conceptualizing how scientists in history formulated hypothesis, made observations, conducted experiments and reached conclusions.

There is a concern about the diversity of historical materials in different areas of science. McComas (2008) concluded that historical materials were given in the discipline of physics more heavily and recommended the use of historical materials in other disciplines so that students can understand the scientific enterprise in varied disciplines. This study is also significant since historical materials in the discipline of biology were used. Circulatory system includes abstract concepts which students cannot observe directly. Those materials may provide deep insights into those concepts through examples and videos used in the present study.

The review of related literature as coupled with the findings of this study provide empirical evidence to establish a relationship between certain elements of scientific literacy and history of science instruction. Researchers, curriculum developers, and science educators who are interested in the utilization and effect of history of science instruction will find related literature and results in this study. By means of reviewed literature, the readers will find the summary of prior research by comparing and contrasting various scholarly articles, books, documents as well as academic theses.

There is also a need for such a study because the national science curriculum aims to develop scientifically literate citizens for future (MEB, 2004). Monk and Osborne (1997) underlined that without integrating some history into the science, science education will not achieve its goals. Instructional approaches proposed to achieve this aim should be investigated and introduced to the teachers so that scientific literacy can be improved.

CHAPTER II

LITERATURE REVIEW

In this chapter, the previous studies related to this study were reviewed. First of all, general overview of scientific literacy was presented including the various definitions of it in science education literature as well as how this study conceptualizes scientific literacy. Then, the role of history of science in science education literature was reviewed and the studies underlining the need for the inclusion of HOS into science classrooms were summarized. Finally, science process skills, science concepts understanding, attitudes toward science, and nature of science literature were reviewed respectively.

2.1 Scientific Literacy

Scientific literacy has become the fundamental objective of science education in curriculum reforms (AAAS, 1993; Dillon, 2009; MoNE, 2006; NRC, 1996). Although scientific literacy has been set as a major goal of science education, there is no agreement about its meaning in science education community (Deboer, 2000; Roberts, 2007). Durant (1993) stated that SL “stands for what the general public ought to know about science” (p. 129). NRC (1996) defined SL as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity". It was added that "scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions" (p. 22). Moreover, The Organization for Economic Cooperation and Development's (OECD) Programme for International Student Achievement (PISA) defined scientific literacy as "the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (OECD, 2003, p. 133). In line with the definition of SL, a person should possess certain characteristics to be scientifically literate. In Science for All Americans (AAAS, 1998), a scientifically literate individual was broadly characterized as follows:

> is familiar with the natural world; understands some of the key concepts and principles of science; has a capacity for scientific ways of thinking; is aware of some of the important ways in which mathematics, technology and science depend upon one another; knows that science, mathematics and technology are human enterprises, and what that implies about their strengths and limitations; is able to use scientific knowledge and ways of thinking for personal and social purposes (p. 6).

Also, Abd-El-Khalick and BouJaoude (1997) stated that "a scientifically literate person should develop an understanding of the concepts, principles, theories, and processes of science, and an awareness of the complex relationships between science, technology, and society. More important, such a person should develop an understanding of the nature of science" (p. 673).

Among these definitions of scientific literacy, AAAS (1998) focused on the knowledge about natural world; key science concepts; science process skills; mathematics, science, and technology relationship; social and cultural embedded aspect of NOS. Similarly, OECD (2003) focused on understanding of science concepts; science process skills; decision on natural world; and science as a human endeavor which is one of the aspect of NOS. Correspondingly, Abd-El-Khalick and Boujaoude (1997) focused on science concepts and science process skills; science, technology, society relationship; and NOS understanding. Although there are some variations between these definitions of scientific literacy, three common points still exists among them; science process skills, understanding science concepts, and nature of science. First, this means that a person should have both basic science process skills such as classifying, inferring, observing, and integrated science process skills such as controlling variables, formulating hypothesis, experimenting, fitting to all scientific ventures to be scientifically literate Second, the person to be scientifically literate should also have at least some level of science content knowledge. Third, the person should have an understanding of nature of science.

In addition to these components, NRC emphasized that attitudes and values also shape a person being as scientifically literate (1996). In recent years, there existed an increased concern for the number of students who choose science as a major due to the decrease in students' positive attitudes toward science (Osborne, Simon & Collins, (2003). Being aware of this, OECD broadened the definition of scientific literacy including attitudes toward science in 2006. In fact there was no explicit reference to attitudes while describing SL in OECD 2003 publication. Hence, a scientifically literate individual should developed science process skills, understand basic science concepts, have favorable attitudes toward science as well as have a developed understanding of nature of science.

Overall, considering abovementioned definitions, in this study scientific literacy was conceptualized as the ability to understand the basic terms in science; to differentiate scientific knowledge from non-scientific one; to question the trustworthiness of knowledge; to note the characteristics of an object or condition using senses; to classify objects and conditions; to forecasting a future event based on past observations or the extension of data; to test a hypothesis; to think critically and evaluate evidence; to pose claims or counterclaims and defend his ideas and reach decisions; to aware that science is a body of knowledge and as a way of knowledge that is created by human endeavor; and to have positive impression toward the science.

Based on this definition, it seems sensible to characterize scientifically literate person as the individual who is updated with recent development in science, can differentiate scientific knowledge from non-scientific one, and questions about the trustworthiness of the knowledge. Moreover a scientifically literate person should inquire the source of the knowledge. S/he should think critically and evaluate evidence. S/he should discuss the alternatives, pose claims or counterclaims and defend her/his ideas and reach decisions. Therefore it is important to educate scientifically literate individuals.

In today's rapidly developing world, there is an increasing need for such individuals. In order to educate scientifically literate individuals, appropriate learning environments should be provided to students. When the literature was investigated, alternative approaches have been suggested by researchers, for example, role playing (Schwartz, 2012); cooperative learning (Soja & Huerta, 2001); science camps (Foster & Shiel-Rolle, 2011); technology-enhanced science classrooms (Kim & Hannafin, 2011); as well as history of science instruction (Dolphin, 2009). Among this incomplete list of approaches, history of science instruction was chosen in this study because, unlike the others, history of science instruction promote students not only for *learning of science* but also for *learning about science* (Monk & Osborne, 1997). In this study, history of science has been recommended as an instructional approach to foster students' scientific literacy. In this regard, the following part was allocated to the related literature about history of science instruction and its role in science education.

2.2 History of Science in Science Education

In the literature, Harvard University was known as a pioneer in the development of history of science as a discipline (Klassen, 2002). Klassen (2002) explained that in 1936, Harvard University offered a PhD program about history of science and science was taught with integrating its history. The next step in the development of HOS was the incorporation of history of science cases into undergraduate program again in Harvard University by Conant in the late 1940s (Russell, 1981). Russell (1981) expressed that historical cases for high school students were developed by

Klopfer in the late 1950s as the next attempt in the development of history of science. Rutherford, Holton and Watson (1970) developed a project called Harvard Project Physics with the aim "to design a humanistically oriented physics course, to attract more students to the study of introductory physics, and to find out more about the factors that influence the learning of science" (p. iii). The authors stated that the more specific goal of the project is to help students understand that physics is a many-sided human activity through presenting the concepts in a historical and cultural context. To achieve this goal, historical materials in physics concepts, such as energy, motion, space and waves, were developed. Kruse (2010) argued that abovementioned curriculum projects could not be adapted by teachers since they either included very long historical reading texts or they little emphasized scientific processes and science concepts. Especially the Harvard Project Physics devoted a whole physics curriculum to history of science and used historical materials as an alternative way for teaching physics without focusing on scientific processes and understanding of physics concept (Russell, 1981). However, Russell (1981) suggested that "if we wish to use the history of science to influence students' understanding of science, we must include significant amounts of historical material and treat that material in ways which illuminate particular characteristics of science" (p. 56). In the following reform movements, (e.g. AAAS, 1989; 1990; 1993) it was observed that HOS should be an integral part of the science education rather than using it as a whole curriculum for teaching science. In science for all Americans (AAAS, 1990) it was emphasized that people should have at least some knowledge of HOS and some of the great episodes in the history of the scientific endeavor.

Thus, aforementioned reform movements emphasized the use of history of science in science education. Parallel to these reform movements, relevant literature provided theoretical and empirical support for the integration of history of science into science classrooms. For example, related literature demonstrated that integration of HOS into science classrooms can lead to improvement in students' *science process skills* (Dedes & Ravanis, 2008; Giunta, 1998; Kolstø, 2008; Matthew, 1994). In the history of science, scientists used a lot of science process skills to generate scientific knowledge, such as formulating hypothesis, collecting data, devising experiments, drawing conclusions. Students should also develop such skills to understand how scientific knowledge is generated. Klopfer (1969) developed historical case studies on physics unit with the aim of developing an understanding of scientific principles. Through these cases, students were expected to understand scientific hypothesis, the relation between ideas and experiments, testing hypothesis by experiments, and establishing theories obtaining experimental evidence. These are related to the scientific inquiry and the skills scientists use in scientific work. While discussing the history of physics, Matthews (1994) referred to the Torricelli's experiment conducted in 1643 to measure air pressure and stated that the same experiment can also be conducted in reference to Torricelli to engage students in science process skills. Metz (2004) argued that the scientific inquiry in science classrooms includes lecture-laboratory style in which students are given worksheets including procedures like a cookbook approach to prove the scientific laws. Instead, he suggested a historical approach for scientific inquiry which includes four steps as context, experimental design, analysis and interpretation of results and explanation. Students were first provided a historical narrative then they collaboratively generate a problem and a design to solve the problem. After, teacher does an experiment which is closely aligned with the historical one. Students then collect data on their own problems and perform experiments to reach scientific explanations. In these steps, students always reflect on their ideas through comparing them with the original ones provided in the historical narratives. Metz (2004) emphasized that through this approach students do not adhere to the procedures in the laboratory manuals to prove scientific laws rather develop an understanding of scientific inquiry.

Apart from improving science process skills, the use of history of science in science classrooms can help students *develop an understanding of science concepts* (Galili & Hazan, 2000; Matthews, 1989; Seker & Welsh, 2006; Seroglou, Koumaras & Tselfes, 1998; Stinner, 1989; Wandersee, 1985). National Research Council (1996) stated that “learning about the history of science might help students to improve their general understanding of science” (p. 200). HOS reveals the historical development of scientific knowledge from past to present including all rival and the most accepted scientific claims. Mayr (1982) highlighted that students' learning of science can be facilitated through learning the past scientific mistakes. Moreover, Wandersee (1985) used history of science to explore students' misconceptions about photosynthesis and suggested that if students are exposed to the historical misconceptions in science content, they can realize their own misconceptions and change them. It was also advocated that HOS have a potential role in making abstract concepts more concrete, therefore more comprehensible for the students (Matthews, 1994; Sarton, 1952; 1962; Tamir, 1989).

Integration of HOS into science classrooms can also have an important role in the development of positive *attitudes toward science*. Russell (1981) argued that "one may say that adding substantial material from history of science can influence students' attitudes" (p. 56). Kubli (1999) also supported the use of HOS to increase students' motivation, participation and interest and the result of his study provided evidence for the positive relation between HOS and favorable attitudes toward science. HOS have a potential to increase students' attitudes toward science through humanizing science, investigating the life and times of scientists in the past, and making subject matter more engaging for students (Matthews, 1994). Moreover, Carvalho and Vannucchi (2000) proposed that HOS can provide teachers with an insight for preparing activities which may catch students' attention and interest.

In addition, according to an important body of literature, HOS integrated science instruction can promote students' *nature of science views* (Bauer, 1992; Clough, 2006; Duschl 1990; Irwin, 2000; Kolstø, 2008; Lin and Chen, 2002; Lonsbury & Ellis, 2002; Matthews 1994; 1998; Monk & Osborne 1997; Roach, 1993). Howe and Rudge (2005) argued that HOS serves as a platform for students to internalize the philosophical NOS ideas. Students may develop understandings for tentative, subjective, empirical, imagination and creativity, inferential aspects of NOS as well as social and cultural embedded nature of science and the difference between theories and laws. Indeed, Irwin's study (2000) showed that students can understand that scientific knowledge grows, scientists use imagination and creativity, and scientific knowledge is not a static body of facts through the use of historical case studies for teaching NOS. In their interpretive study, Abd-El-Khalick and Lederman (2000) used a historical context to emphasize the aspects of NOS and concluded that HOS with explicit and reflective NOS approach can be effective in developing NOS views. Supporting Abd-El-Khalick and Lederman’s findings, Clough (2006) noted that the important issues in NOS such as discovery or invention, the nature of evidence, scientists' commitment to the earlier studies can be enlightened through a highly contextualized approach. Clough (2006) explained that highly contextualized approach means "integrating historical and contemporary science examples that are tied to the fundamental ideas taught in particular science subjects” (p. 474). Clough (2006) argued that this approach places the content in a human context, demonstrates difficulties scientists encounter in generating new concepts with evidence, reveals the gradual development of scientific knowledge, and exemplifies epistemological and ontological issues which are essential to understand NOS.

To sum up; history of science instruction can be an alternative way to impact students' science process skills, understanding of science concepts, attitudes toward science, and nature of science views in a positive way. The detailed literature about each variable, including the relation between HOS instruction and the variable, was presented throughout the following parts.

2.3 Science Process Skills

Science process skills are considered to be one of the integral part and cornerstone of science education by many researchers (DiSimoni, 2002; Gerald Dillashaw & Okey, 1980; Harlen, 1999; Roth & Roychoudhury, 1993; Solano-flores, 2000; Turpin, 2000). Padilla (1990) underlined that “scientific method, scientific thinking and critical thinking have been terms used at various times to describe these science [process] skills” and added that “these skills are defined as a set of broadly transferable abilities, appropriate to many science disciplines and reflective of the behavior of scientists” (p. 1).

Science process skills divided into two groups, namely basic science process skills, and integrated science process skills (Shaw, 1983). Basic science process skills comprise "observing, measuring, inferring, predicting, classifying, and collecting and recording data" and integrated science process skills comprise "interpreting data, controlling variables, defining operationally, formulating hypothesis, and experimenting" (Shaw, 1983, p. 615). Instructors should teach these skills because routinely teaching them will increase the possibility that students will improve their science process skills and will be able to use them in scientific inquiries (Wilke & Straits, 2005). Therefore researchers examined the effectiveness of different instructional strategies that foster the acquisition of science process skills.

For example; Turpin (2000) used a quasi-experimental design to explore the effect of integrated, activity-based instruction on students' attitudes toward science, learning of science and science process skills. While the experimental group students (*N* = 531) received integrated, activity-based instruction; the control group students (*N* = 398) followed traditional curriculum. Both groups' science process skills were measured before and after the implementations. The researcher found that the groups' science process skills test scores at post-measurement were significantly different than each other after controlling their pretest scores. This difference was in favor of experimental group.

DiSimoni (2002) studied with 24 students while investigating the effect of writing on fourth-grade students' development of science concepts and science process skills. The researcher formed two group, an experimental (*N* = 12) and a comparison group (*N* = 12). Both group participated similar science activities which aimed to develop learning of science. However, experimental group students completed written response tasks just before or immediately after each activity. The implementation lasted for 8 weeks. The researcher found that experimental group students did not outperformed comparison group in terms of science process skills.

Sullivan (2008) conducted another study to investigate the relationship between an intensive robotics course offered during a summer camp and science process skills in sixth grade students. A pre-post test design was used. The course was 3-week long with 100 hours of robotics coursework. The course included Lego construction kits and a software. The investigator and the instructor taught the class through direct instruction and student-directed inquiry. First a short-lecture was delivered then students worked in pairs to solve the problems. They also engaged in problem solving activity individually. Problems included challenges which forced students to build a structure to accomplish a task. Through this course, students learned basic concepts in computer science as well as gears, types of gears, and gear ratios. Data were collected through videotapes of problem-solving sessions. Students were told to think aloud during activity. These videotapes were transcribed and analyzed qualitatively for thinking skills and science process skills and the observed codes were observation, evaluation of a solution, hypothesis generation, hypothesis testing, control of variables, manipulation and computation. The results showed that all students used observation and evaluation of solution skills. Twenty five students used manipulation, hypothesis generation, control of variables, and hypothesis testing skills. Twenty four students used estimation skills and 11 students used computational skills while they solve the problem. The results showed that students attended the course utilized thinking and science process skills to solve a robotics problem. The authors argued that the use of open-ended and students guided inquiry in the robotics course leads to the use of thinking and science process skills.

Yager and Akcay (2010) conducted a quasi-experimental study to compare the relative effectiveness of inquiry teaching and learning method with traditional textbook approach. A total of 365 students participated in inquiry classes while 359 students participated in traditional classes. Twelve teachers taught these classes.

The authors used Iowa Assessment Package for the Chautauqua Program developed by (Enger & Yager, 2001) to collect data. This package included different instruments to measure outcomes in different domains such as concept domain, process domain, creativity domain, and application domain. The process domain included learning skills scientists use as they seek answers to their questions about the universe. The results indicated that students who experienced inquiry science teaching developed science process skills significantly more than students who experienced traditional science teaching. The authors discussed that inquiry allowed students use science process skills themselves rather than using them in structured science laboratories to prove what scientists did.

Science process skills have also become an integral part of science curriculum in Turkey. Being aware of this, Cakiroglu and Aydin (2009) investigated the distribution of science process skills (SPS) in current science and technology curriculum through grades 4 to 8. They examined the objectives of the curriculum in terms of targeting basic and integrated science process skills. The objectives referring to basic or integrated SPS were calculated and related tables were provided for each grade level. The result of the study revealed that the distribution of SPS was not distributed homogenously, favoring comparing-classifying in grade 4 and 5, and observing through grade 6 to 8; while disfavoring forecasting through grade 4 to grade 8. The researchers also found that the curriculum's focus on basic science process skills decreased gradually from grade 4 to 8 while there was a balanced increase in integrated science process skills. Cakiroglu and Aydin suggested that all of the science process skills should be stressed equally to have a balanced curriculum.

Yildirim (2012) studied the impact of guided inquiry on students' acquisition of science process skills on the topic of buoyancy force. For this aim, he selected a sample of 55 students from 3 intact classes in grade eight. Among them, 2 classes randomly assigned as experimental group and learn the topic through guided inquiry experiments; while other class assigned as control group and learn the topic through traditionally designed experiments during five-week periods. Participants attitudes were evaluated using science process skills test (Burns et al., 1985) at the beginning and at the end of the treatments. The result of the study pointed out that both group increased their SPST scores. However, experimental group did not substantially outperform over comparison group after the instruction.

Similarly, Koksal and Berberoglu (2014) studied the effectiveness of guided-inquiry approach on 6th grade students’ science process skills through a non-equivalent control group quasi-experimental design. A total of 144 sixth graders were instructed with guided-inquiry teaching while 160 students were instructed with the traditional teaching and learning in the unit of *Reproduction, Development and Growth in Living Thing.* The authors developed a science process skill test to assess skills such as observing, classifying, proposing hypotheses, controlling and manipulating variables, processing data, and formulating model. There were 16 items in the test including a variety of items such as multiple choice, open-ended questions, and matching item. The results indicated that there are significant differences between experimental group and control group in terms of science process skills. The students instructed with guided-inquiry approach performed better on science process skill test than the students received traditional instruction.

Taskin-Can (2013) investigated the effect of another instructional strategy which was creative-drama-based instruction on fifth grade students' science process skills through a quasi-experimental design. A total of 60 students participated in the study. Experimental group students learned science with creative drama-based instruction while the control group learned science through lecture and discussion methods. The treatment lasted for three weeks and included an introduction phase (warm-up activities), development phase (experiencing ideas through plays), and quieting phase (revision of key concepts). The results showed that the creative drama-based instruction was statistically better in improvement of scientific process skills in the fifth grade students.

Another study focusing on science process skills in Turkey was conducted by Kula. In this study, Kula (2009) evaluated the effect of inquiry-based science instruction on grade 6 students' science process skills, science content knowledge, and attitudes toward science. The sample of the study included 60 students divided equally into experimental and control group. Experimental group students engaged in inquiry-based instruction while control group followed current science and technology curriculum. During the study, researcher focused on skeletal system, circulatory system, and respiratory system. The groups' scores were compared based on pre-post measurements. In terms of science process skills, the result indicated that both groups developed their science process skills after the implementation. However, there was not a statistically significant difference between experimental and control group at pre- and post- measurements.

In the studies that are outlined above, there is not any reference to the effects of history of science instruction on science process skills. However, Allchin (1992) argued that history of science instruction may contribute to the development of students' science process skills. According to Allchin, one of the purposes of teaching science through its history is to develop students' science process skills. Allchin (n.d.) stated that "when students are allowed to recapitulate history in their own development, they also develop the skills of doing science". Yip (2006) proposed a positive association between nature of science and scientific processes. She used history of science instruction to develop nature of science views and concluded that establishing nature of scientific knowledge will also provide opportunities for thinking inherent to the scientific inquiry. For example, understanding nature of science aspects such as observation, inference, empirical-based can result in understanding of scientific processes to produce scientific knowledge. Giunta (1998) developed a general education science course for non-science majors with integrating Conant's ideas about case histories. She aimed to teach non-science majors how scientists carry out scientific research and to approach science as a way of knowing rather than as a body of knowledge. She used the discovery of argon as the historical case. However this paper only provided a historical material. That is, it did not investigate whether non-science majors developed their ideas about scientific method after attending this course.

Recently Vincent (2010) developed a lesson in which he used historical examples to stress science process skills. He is inspired from Deese, Ramsey, and Cox (2007) who suggested that demonstration could be used in favor of supporting inquiry skills. In this lesson, Vincent used van-Helmont's experiment in which he tested what proportion of the mass of tree is coming from the soil. Students did not reconstruct the experiment (due to the fact that the actual observation lasted for five years), but they were provided step by step instructions. The summary of the experiment was as follows. Van-Helmont planted 2.26 kg willow tree to 90.7 kg dry soil. He took care of the tree and watered it for 5 years, and re-measured both the tree and the soil at the end of fifth year. The core question was "after five years, what happened to the mass of the dirt [soil]?" (Vincent, 2010, p. 67). Before having students' predictions, he allowed students to ask question about the design of the experiment. By means of this step, it was assessed whether students could comprehend the experimental design, including what is experimental and control groups, what kind of data should be collected in particular setting, what kind of variables should be controlled and manipulated. The researcher clarified that students asked various questions that he did not know, for instance the exact amount of water used by van-Helmont. In such instances researcher encouraged students to think on that in order to let them brainstorm about how it affects the result. In the next step, Vincent allowed students to write their predictions about the remaining mass of the soil at the end of five years as well as their justifications. He reported that significant majority of students predicted that the mass of the soil would decrease. After allowing students to make a whole-class discussion about their prediction, Vincent declared the final mass of the soil as 90.6 (nearly unchanged) and the willow tree as 76.7 kg (an increase more than 30 times). Vincent stated that a majority of students predicted that the soil would lose its major mass at the beginning of the study; therefore they eagerly make classroom discussion on this topic. During classroom discussion most of the students inferred that most of the mass of willow tree comes from water not from soil. Vincent underlined that van-Helmont also deduced similar conclusion about the mass of tree. Today, it is known that, this is also a partially correct answer because a tree's mass mostly come from CO_2 used in photosynthesis to produce glucose. Vincent concluded that through using van-Helmont's experiment, students can comprehend how science works. Moreover he added that

> historical-narrative method is that the teacher has control over the data students are expected to analyze (much like a demonstration), allowing students to be more focused on the scientific concept of the lesson... as a way to nurture science process skills in students while still focusing on the science content. Having students predict, analyze, interpret data, and question are skills that are easily integrated within the method (p. 69).

A thorough literature review showed that although HOS was emphasized to teach scientific processes and scientific inquiry, little empirical evidence provided for the relation between HOS and science process skills. The researcher also did not come across with a specific study examining the effect of HOS on science process skills in Turkey. HOS studies are really scarce in Turkish context. This study can contribute to this gap in the literature through providing a relation between HOS and science process skills with a Turkish sample.

2.4 Understanding of Science Concepts

One of the goals of science education is to develop students' understandings of science concepts (AAAS, 1998; Abd-El-Khalick & BouJaoude, 1997; Hurd 1997; Laugksch 2000; Miller 1983; OECD, 2003; Solomon 2001). Peters (2012) argued that "science students are expected to understand the body of knowledge known as scientific facts ... in order to be scientifically literate" (p. 881). Researchers have utilized a variety of teaching strategies to improve students' understanding of science concepts. An incomplete list of examples might include creative drama (e.g. Hendrix et al., 2012), inquiry based science instruction (e.g. Geier, et al., 2008), argumentation (Zohar & Nemet, 2002), socioscientific issues based instruction (e.g. Klosterman & Sadler, 2010), history of science instruction (e.g. Kim, 2007), laboratory instruction (e.g. Freedman, 1997). In these studies the researchers focused on science content knowledge in different areas such as biology (e.g. Zohar & Nemet, 2002; Klosterman & Sadler, 2010) and physics (Seker, 2004).

Hendrix et al. (2012) integrated creative drama into an inquiry-oriented science instruction with the purpose of improving fourth and fifth grade students' understanding of science concepts in sound physics and solar energy. The instrument used to measure students' learning in science was Full Option Science System developed in University of California as a result of 20-year long research project. The result of the study indicated that treatment group receiving creative drama improved their learning of science significantly than control group. Authors argued that creative drama helped students understand abstract concepts through facilitating students' retention of both scientific concepts and vocabulary.

Zohar and Nemet (2002) examined the effect of Genetic Revolution Unit on genetics knowledge among Grade 9 students. The unit included learning activities designed to foster higher-order thinking skills and scientific argumentation in the context of moral dilemmas as well as learning in human genetics. Experimental group (N = 99) learned the genetics concepts through this unit. A total of 12 hour unit including 10 moral dilemmas in genetics were implemented in experimental group. The comparison group students (N = 87) learned the same concepts through traditional methods including a booklet about the topic. Teacher first taught the information in the booklet then asked questions to the students in comparison group. Both groups' genetics knowledge was assessed before and after the implementations. The results indicated that experimental group students gained significantly more genetics knowledge than students in the comparison group. The authors concluded that teaching science concepts through tasks which foster higher-order thinking skills enabled students actively construct mental representations of the concepts which, in turn, increased the learning of science.

In order to increase science concept understanding, socioscientific issues (SSI) based instruction has also been suggested as a context for learning science. In their study, Klosterman and Sadler (2010) aimed to explore the effect of SSI-based curriculum on grades 9-12 students' learning of science in global warming. They developed a three-week unit consisting of seven learning activities for 15 hours. They aimed to display the scientific principles and processes behind global warming through this unit. Data were collected from two classes before and after the unit through curriculum-aligned and standards-aligned tests to assess content knowledge gains. The results showed that students' post-instruction science knowledge levels were higher than pre-instruction. Authors advocated that SSI-based instruction can advance students' learning of science content knowledge. However they stated that this study is limited in suggesting a causal relationship due to not having a comparison group.

Sungur et al. (2006) investigated the effect of problem-based learning on 10th grade students' academic achievement in human excretory system unit. Two classes including 61 students taught by the same teacher participated in the study. A static group comparison design was used. One of the classes was assigned to experimental group and received instruction through problem-based learning. The other was assigned to control group and received traditionally-designed biology instruction. Both group received the treatment for four weeks, four times in a week for 40-minute class sessions. The researchers developed the *Human Excretory System Achievement Test* including 25 multiple-choice questions related to the function and structure of the excretory system. The problem-based learning was found to be statistically superior to the traditional instruction in acquisition of scientific concepts. The students receiving problem-based learning performed better on items requiring higher order thinking skills and were able to use relevant information in solving problems better than traditional group students.

Boz and Uzuntiryaki (2008) aimed to develop 6^{th} grade students' understanding of the states of matter concepts through case-based instruction. A non-equivalent pretest-posttest group design was used. Two 6^{th} grade classes were involved in the study as experimental and control group. Experimental group students were taught with case-based instruction while the control group students were instructed with traditional approach. In the experimental group real world problems and scenarios were utilized as a case. Four different cases including the concepts evaporation, sublimation and condensation of water were developed. Each case included a scenario and a series of questions about it. First students read the scenario and answered the following questions as individually then as a group. Then teacher-guided class discussions were carried out to facilitate students' learning of the concepts. Finally students were engaged in the application of the concepts learned to new situations. States of Matter Concept was developed by the researchers and administered to each group before and after instructions. The results revealed that case-based instruction provided significantly better gains in learning the states of matter concepts than traditional approach. The authors concluded that allowing students to interact with each other and making science relevant and meaningful through cases help students comprehend scientific concepts better.

NRC (1996) stated that “learning about the history of science might help students to improve their general understanding of science” (p. 200). Monk and Osborne (1997) asserted that when the development of scientific knowledge i.e. history of science, be a part of implemented curriculum in schools, students will retain their science knowledge better. They grounded this claim in two important reasons. First, they asserted that students will understand their inadequate thoughts more reasonably in science classes by means of HOS, because they will realize that some of the ancient scientists also thought in similar ways. Second, students will appreciate the recent thought in science because it provides detailed and more developed idea than students hold currently. This will lead students to be aware of their own insufficient conceptions and stimulate them to examine current scientific knowledge. Hence they will be more motivated to study science by realizing the similarity between ancient scientists and their own way of thinking (Monk & Osborne, 1997). Rudge and Howe (2009) also suggested that HOS instruction is important for students to bridge the past and present which will provide them to develop a sense of the modern perspective in science.

In the literature there are limited studies examining the role of HOS instruction on understanding of science concepts. In one of these studies which examined the effectiveness of HOS instruction, Galili and Hazan (2000) designed a year-long course and incorporated historical activities into their course. They compared experimental group (*N* = 141), what they called "innovative instruction", with a control group (*N* = 93), what they called "regular instruction". The result provided evidence that HOS groups did better at learning science subject than comparison group. Similarly, Lin (1998) studied the effectiveness of incorporating HOS into chemistry education. The results revealed that the students engaged in historical material developed better conceptual problem solving ability. However Irwin's (2000) study which examined the effect of HOS instruction on teaching and learning science revealed that HOS instruction did not lead to a better understanding of science concepts. Irwin also added that HOS did not interfere with understanding of science, though. The study of Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, and Erduran, (2005) also pointed out that experiments that simulated the ancient ones led to a better learning and comprehension of the material. The study of Seker (2004) mentioned also investigated the effect of HOS on learning science in motion and force units. He could not find significant relation between HOS and meaningful learning of motion and force concepts.

Kim (2007) conducted a study including history of genetics. She wanted to explore the effect of instruction with history of genetics on the students' understanding of genetics concepts and nature of science. She emphasized that knowing science concepts and nature of science is essential parts of scientific literacy. She also emphasized that history of science can serve as a means to improve students' understanding genetics concepts and nature of science concepts. She used constructivist teaching methods in both experimental and control group while in experimental group, she utilized the history of genetics combined with related nature of science aspects. She found that instruction with history of science teaching improved students' understanding of nature of science concepts while their understanding of genetic concepts did not differ in both experimental and control group.

As clear from the studies summarized above, there is a substantial divergence in the literature regarding the effect of incorporating HOS in order to develop understanding of science concepts. Needed are more studies that focus on the incorporation of HOS instruction into classroom settings to better understand the association between HOS instruction and understanding of science concepts.

2.5 Attitudes toward Science

About a century ago, researchers were interested in assessing attitudes empirically (Maio & Haddock, 2009). Maio and Haddock (2009) stated that the frontiers in this field were Louis Thurstone and Rensis Likert who developed a number of ways for measuring attitude. In 1928, Thurstone argued that attitudes can be measured through acceptance or rejection of opinions and defined attitudes as "the sum of total of a man's inclinations and feelings, prejudice or bias, preconceived notions, ideas, fears, threats, and convictions about any specified topics" (p. 531). Likert (1932) was also influential in measuring attitudes through developing an attitude scale including five different choices which ranged from *strongly approve* to *strongly disapprove*. In this scale, individuals stated their degree of approval or disapproval. Likert-type scale was named after its inventor Rensis Likert, who guided most of the attitude scales in future research. Also, Thurstone (1928) and Likert's (1932) studies were significant in terms of showing that attitude, as a construct, can be measured quantitatively.

As many other constructs, the definition of attitudes could not achieve a common acceptance among researchers. One of the earlier definitions of attitude came from Gordon Allport (1935). He defined attitude as "a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon an individual's response to all objects and situations with which it is related" (p. 810). Eagly and Chaiken (1993) defined attitude as “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor” (p. 1). Petty and Cacioppo (1996) also described attitude as “a general and enduring positive or negative feeling about some person, object, or issue” (p. 7). Attitude was considered as an important construct because of its impact on human actions. For example, Maio and Haddock (2009) emphasized that attitudes "influence how we view the world, what we think, and what we do" (p. 4). Attitudes are also important in the field of education. Mager (1968) explained the role of attitudes in education as "The likelihood of the student putting his knowledge to use is influenced by his attitudes for or against the subject; things disliked have a way of being forgotten" (p. 11). Therefore students' attitudes toward schools subjects are vital for their understanding and use of the subject matter as well as retention of it. In light of this, attitudes have been emphasized in science education literature since 1960s (Koballa, 1995). There are two relevant, yet different, attitude terms used in science education literature, namely *attitudes toward science* and *scientific attitude*. The former refers to "a general and enduring positive or negative feeling about science" (Koballa & Crawley, 1985, p. 223). The latter describes the characteristics of a scientist such as "curiosity, rationality, open-mindedness, critical mindedness, objectivity and intellectual honesty, willingness to suspend judgment, humility, and reverence for life" (Ochs, 1981, p. 37). It is important to point out that scientific attitudes are not an expression of personal feeling toward science (Al-Kharboush, 2003) therefore it is not within the scope of this study. The concern of this study is *attitudes towards science*.

Unquestionably, the studies about attitudes have provided a basis for the elaboration of the concept *attitudes toward science*. Klopfer was known among the first researcher who made a notable contribution to the emergence of the term *attitudes toward science,* (Lado, 2011; Osborne et al., 2003). Klopfer (1971) classified attitude and interest within six categories. These are: behaviors which manifest favorable attitude toward science and scientist, acceptance of scientific inquiry as a way of thought, adoption of scientific attitudes, enjoyment of science learning experiences, development of interest in science and science-related activities, and development of interest in pursuing a career in science or science-related work. Klopfer's categorization guided Fraser's study (1978) in which he developed Test of Science Related Attitudes (TOSRA) which was the instrument used in this study. The details related to the TOSRA and the rational for its use in this study were provided in Methodology chapter.

In science education literature, there are a number of studies which focused on teachers' attitudes toward science (e.g. Bitner, 1993; Pecore, Kirchgessner, & Carruth, 2013; van Aalderen-Smeets, Walma van der Molen, & Asma, 2012; Westerback, 2006) and students' attitudes toward science (e.g. Freedman, 1997; Houseal, Abd-El-Khalick, & Destefano, 2014; Morrell & Lederman, 1998). In this study, the students' attitudes toward science were investigated.

Freedman (1997) emphasized that "instruction that makes science more exciting and encourages students (e.g., laboratory) has a positive influence on students' attitude toward science and their achievement" (p. 344). This idea advanced different instructional strategies that aimed to develop positive attitudes toward science. Koballa and Glynn (2007) also defended that science instruction should have a potential to develop favorable attitudes toward science to be called as effective instruction. In light of this, the studies utilizing different instructional strategies were conducted to develop students' favorable attitudes toward science.

The study of Freedman (1997) utilized posttest only control group design to investigate the impact of hands-on laboratory program on students' attitudes toward science. Twenty physical science classes were randomly assigned to treatment and control groups. The students in experimental group carried out laboratory activities for the physical science topics in small groups once a week for 36-week period. The control group did not received laboratory instruction. Laboratory activities were either obtained from laboratory manuals or designed by the researcher for the physical science classes. Students' attitudes toward science were measured using the adapted version of Q-sort by Humphreys (1975). The analysis of the questionnaire revealed that the mean attitude scores of the experimental group were higher than control group although this difference was not statistically significant. The author stated that although the result was not significant, the obvious difference between mean attitude scores of two groups supported the positive impact of laboratory instruction on students' attitudes toward science.

Exploring the effects of visiting space center on elementary students' attitudes toward science, Jarvis and Pell (2005) studied with 300 students drawn from 4 different schools, aged 10 and 11 years. All students visited National Space Center in United Kingdom (UK) which is largest attraction center devoted to space science in UK. The data were collected five times in the course of the study. Those are, one month before the visit, observation during the visit, one week after the visit, two months after the visit and four months after the visit. Result of the study indicated that the interest of participants toward space increased substantially right after the visit while their appreciation of the role of science on society increased moderately. Also, the researchers found that both boys and girls still exhibited more favorable attitudes toward being scientists two months after the visit. They concluded that two additional external factors also influence students' retention of positive attitudes: the support of teacher throughout the visit and teacher own interest toward the visit.

Cakir (2011) studied with Turkish sample from 6th grade level and compared the relative effectiveness of argumentation-based and curriculum-based instructions on students' attitudes toward science, conceptual understandings of physical and chemical change topic, and argumentativeness. For this purpose, she randomly selected 32 students for experimental group and 33 students for comparison group. Physical and chemical change topics were addressed in both groups. Researcher used Toulmin's (1958) argumentation pattern to prepare the activities in experimental group and she followed curriculum-based instruction in control group. Science Attitude Scale, which was originally developed by Geban, Ertepinar, Yilmaz, Altin, and Sahbaz (1994), was administered to both groups before and after the instructions in order to measure the change in students' attitudes toward science. The result indicated that experimental group students' attitude scores increased while comparison group students' scores decreased after the instructions. The mixed between-within subjects ANOVA also confirmed that experimental group students' scores were significantly higher than comparison group.

The study of Hendrix et al. (2012), whose details given before, also investigated the effect of creative drama on students' attitudes toward science. Two small group classes (N = 9, N = 10) participated in the study as treatment groups and two classes (N = 12, N = 7) as control groups. They used *Three Dimension Elementary Science Attitude Survey* (Zhang & Campbell, 2010) to measure students' attitudes before and after the instructions. Interestingly, the result of the study indicated that both groups' positive attitudes toward science decreased statistically.

The recent work of Houseal et al. (2014) examined the impact of a student-teacher-scientist partnership on students' attitudes toward science. This partnership included activities designed to engage students in authentic science experiences. A quasi-experimental, pre-test-post-test, comparison group design was utilized to find out the improvement in students' favorable attitudes toward science. A total of 193 students from five to eight grade involved in the intervention group while a total of 187 students from four to six grade included in comparison group. Students' attitudes toward science was measured through four scales of TOSRA which were normality of scientists, attitude to scientific inquiry, leisure interest in science, enjoyment of science lessons. The results showed that the intervention group developed positive attitudes toward science on the normality of scientists subscale. On the other hand both groups exhibited more negative attitudes at post-test on the leisure interest in science subscale. However the comparison group showed significantly increased negative attitudes than intervention group. In terms of attitude to scientific inquiry and enjoyment of science lessons subscales, no significant change was found. The authors concluded that students showed increased positive attitudes regarding their perceptions of scientists.

In addition to instructional strategies mentioned above, history of science instruction was also used to foster students' positive scientific attitudes toward science. Gallagher (1991) argued that if teachers have tendency toward incorporating HOS into their science classes, this will be due to the idea that it will promote favorable attitude toward science because HOS humanize science. Monk and Osborne (1997) characterized science curriculum which only focuses on science content knowledge as "one-dimensional" and complained that it could not accomplish to develop even basic scientific literacy among students and could not develop favorable attitudes toward science. Huybrechts (2000) reported that the number of studies which evaluated the effect of HOS instruction on students' attitudes toward science is insufficient in the literature. As a solution to these drawbacks of current science curriculum, they suggested that researchers are supposed to make consistent attempt to incorporate HOS to science classes.

Solbes and Traver (2003) attempted to improve students' attitudes toward science through integrating history of science into physics and chemistry classes. For this aim they designed different activities with a historical approach to emphasize many aspects of scientific processes, such as how scientific knowledge is achieved and improved. They added some laboratory work and some important dilemmas occurred in the history. Authors studied with secondary school students (age range from 15-17) who were assigned to control and experimental groups randomly. A total of 694 students were included in control groups and received traditional instruction in physics and chemistry classes. The experimental groups included 233 students received history of science instruction in physics and chemistry classes. Authors administered a questionnaire about interest and attitudes toward science to each group during the middle of the term of the school year. The results showed that there was an improvement in students' attitudes toward science after learning physics and chemistry through a historical approach. It was concluded that it is possible to change students' attitudes toward science and to increase their interest in science through adding some history of science to physics and chemistry classes.

Seker (2004) investigated the effect of a four-month-long history of science instruction on learning science, understanding the nature of science, and students' interest in science in *motion and force* units. The participants were 94 eighth grade students randomly assigned to four classes who were instructed by the same science teacher. The author developed three different contexts as history of scientific concepts, the nature of science, and stories from scientists' personal lives. The three classes were taught by one of these contexts while the fourth class received the same instruction given in previous years. Before and after treatments, three constructs were measured. Students' learning science was measured through concepts maps. Students' interest in science was assessed an interest survey developed by Matthew Mitchell (1992). Finally Perspectives on Scientific Epistemology instrument developed by Abd-El-Khalick (2002) was used to assess the nature of science understandings. In terms of interest in science, the results revealed that stories about scientists' personal lives affected students' interest in science.

Mamlok-Naaman et al. (2005) investigated the effect of a historical approach for teaching science on attitudes of 10th grade students who chose not to major in science. A total of 90 students in three classes (each in a different school) participated in the study. Three experienced teachers taught the classes about the structure of the matter using the module "Science: An Ever-Developing Entity"

(Mamlok, 1995). Data were collected through interviews with the students, observation of classroom activities, and informal conversations with the students. The focus of data collection techniques was to gain detailed insights and understanding about students' attitudes toward science. The results of this study revealed that after studying the module, students' attitudes toward science changed. They were more interested in science and displayed positive attitudes toward science using a historical approach. Students, who did not choose science as a major, displayed more interest and curiosity toward science through studying historical events. They stated that the activities were enjoyable and increased their interest in science.

To sum up attitudes toward science is vital for students’ interest in science and scientific inquiry. Positive attitudes toward science can be influential in studying science. Teachers should utilize different approaches for teaching science which cultivate positive attitudes toward science. HOS can be a good alternative for this since episodes of great scientists, scientific discoveries, the experiments scientists performed in the past may have a potential in catching students’ attention and increasing their attitudes toward science. This study can contribute to the literature by displaying causal relationship for whether HOS develops positive attitudes toward science.

2.6 Nature of Science

As a central component of scientific literacy (e.g. Bell & Lederman, 2003; Bybee, 1997; NRC, 1996), it is important to know what science education community means by referring to nature of science. While describing nature of science, Lederman (1992) stated that it refers to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its' development. More broadly, Clough (2006) expressed that

> The phrase 'nature of science' (NOS) is often used in referring to issues such as what science is, how it works, the epistemological and ontological foundations of science, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavors (p. 464).

Undisputedly, the translation of nature of science tenets into classroom practices is essential to achieve scientific literacy. Which tenets of nature of science should be focused at precollege level is the key point that needs to be taken into consideration. Several studies provided suggestions for these tenets (Akerson, et al., 2000; Khishfe & Abd-El-Khalick, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003, Peters, 2012). According to Lederman et al. (2002) and Lederman (2007), these tenets suggest that scientific knowledge is tentative, empirical based; subjective (theory-laden). They also referred that science involves human inference, imagination, and creativity and it both affects and is affected by society and culture (socially and culturally embedded). Three additional important aspects are the distinction between observation and inference, the lack of universal method for doing science, and the function of and relationships between scientific theories and laws. In this study, tentative, subjective, empirical, creative and imaginative, and inferential aspects of NOS were aimed to be developed. Hence only these aspects were explained among others.

Tentative nature of science: One of the core characteristics of scientific knowledge is its tentativeness. This aspect premises that scientific knowledge is not absolute or definite at all (Lederman et al., 2002). In other words, it is subject to change (Khishfe & Abd-El-Khalick, 2002). Lederman, Schwartz, Abd-El-Khalick, and Bell (2001) discussed some of the factors which induce scientific knowledge to change. These are availability of new evidence, technological advancements, the change in the way of thinking, reinterpretation of existing data, the influence of cultural change on individual and community behavior, and the change in the direction of research program. Regarding tentative NOS, AAAS (1993) also referred that "scientific knowledge is subject to modification as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way" (p. 7). Because of tentative nature of science, it is appropriate to conclude that all hypothesis, theories, even laws are subject to change (Bauer, 1992).

Subjective nature of science: An examination of the nature of science literature illustrates that this aspect also refer to "theory-laden" nature of science (Akerson, Cullen, & Hanson, 2009; Bell, Lederman, & Abd-El-Khalick, 2000; Lederman et. al., 2002; Rudge & Howe, 2009). Subjectivity explains that scientists' theoretical dispositions, mindset, beliefs, earlier knowledge, practice, skills, as well as their expectations may manipulate and influence how they do science (Lederman, 2007).

While referring to the role of subjectivity, Bauer (1992) defended that scientists are human and as "all other human beings [they] vary in ability, competence, dedication, and honesty (p. 32). He added that "when science is pictured as so impersonal and ascetic an activity, how to understand that scientists *do* throw their hearts into their work, which also cannot and is not all done by formulas?" (p. 33).

Empirical nature of science: This tenet proposes that the knowledge in science develops or comes from observing the natural world (Lederman et al., 2002). This aspect also refers that the explanation in science are expected to be consistent with evidence. While setting the standard of NOS for sixth grade students, AAAS emphasized that "Scientists do not pay much attention to claims about how something they know about works unless the claims are backed up with evidence that can be confirmed with logical arguments" (AAAS, 1993, p. 11).

Creative and imaginative nature of science: National Science Education Standards expressed that "Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skill, and creativity" (NRC, 1996, p. 170). Similarly, Lederman (2007) argued that science entails plenty of creativity which guides scientists to originate scientific explanations. Creative and imaginative aspect of NOS allowed scientists to create practical explanation of scientific ideas, such as black holes and atoms, which are not "faithful copies of reality" (Lederman, 2007, p. 834).

Inferential nature of science: The accumulation of the body of knowledge in science requires making observations as well as drawing inferences. Therefore students are expected to differentiate the distinction between the two. Observations are the act of careful recognizing and noticing of anything by means of five senses or the extensions of the senses (Lederman, 2007). It was noticed that it is easy to reach consensus about observations (Lederman et. al., 2002; Lederman, 2007). Inferences, on the other hand, are the explanations or interpretations of observations. It is clear that reaching consensus in drawing inference is not as easy as in making observation. Regarding the role of inference, Leager (2008) emphasized that human beings "continually filter and compare their observations with the constructed knowledge of their personal background experiences and related assumptions" (p. 48). Understanding the difference between observation and inference is crucial in that students could make sense of the scientific endeavor and the importance of theories in science (Lederman et. al. (2002).

The way to translate abovementioned aspects into classroom practices is another important point that needs to be discussed. In general, the translations of efforts into classroom practices have taken two forms, namely *implicit* and *explicit* NOS instruction. Several researchers explained the differences between the two (e.g. Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Bell et al., 2000; Khishfe, 2008; Rudge & Howe, 2009). According to Abd-El-Khalick and Lederman (2000) implicit approach assumes that "understanding of NOS is a learning outcome that can be facilitated through process skill instruction, science content coursework, and doing science" (p. 673). The proponents of this approach argue that students will understand the complex epistemology of science (i.e. nature of science) by doing science and suggest to use inquiry activities and hands-on activities developing process skills to enhance NOS conceptions (Khishfe and Abd-El-Khalick, 2002). On the other hand, explicit approach use "elements from history and philosophy of science and/or instruction geared toward the various aspects of NOS" to enhance NOS conceptions (Abd-El-Khalich & Lederman, 2000, p. 673). Schwartz and Lederman (2002) clarified that the character of explicit instruction require actively engaging students' attention to targeted NOS aspects through in-class activities such as discussion and questioning. They further suggested that NOS should be addressed in a similar way as other cognitive learning outcome. An examination of NOS literature provided evidence that explicit NOS instruction is more successful than implicit instruction in enhancing students' conception of NOS (e.g. Khishfe & Abd-El-Khalick, 2002). Abd-El-Khalick and Lederman (2000) discussed two underlying reasons of implicit approach to be less effective than implicit approach. First, implicit approach assumes NOS as an "affective" learning outcome. Second, learners' involvement in science-based activity considered to be sufficient for learning about NOS in implicit approach.

In addition to the explicit approach, science education community added *reflective* elements to the explicit approach (Khishfe & Abd-El-Khalick, 2002). Khishfe and Abd-El-Khalick (2002) suggested that reflected elements means "providing students with opportunities to analyze the activities in which they are engaged from various perspectives (e.g., a NOS framework), to map connections between their activities and ones undertaken by others (e.g., scientists), and to draw generalizations about a domain of knowledge (e.g., epistemology of science)" (p. 555). Recently, Rudge & Howe (2009) critically analyzed related NOS literature and concluded that "nature of science issues should be integrally incorporated as a planned instructional outcome of science lessons (activities and discussions), rather than left implicitly for students to figure out on their own or added on as a tangential discussion topic" while referring to explicit NOS. They also suggested that NOS instruction should be reflective which means "students need to be encouraged to develop more sophisticated understandings of nature of science issues as a result of their own deliberations, as well as come to recognize the implications of insights gained from discussions about particular examples for their understanding of science in general" (p. 563).

In the NOS literature there are two mainstreams. Researchers either explore participants' existing NOS views without attempt to change (e.g. Dogan & Abd-El-Khalick, 2008; Kilic, Sungur, Cakiroglu, & Tekkaya, 2005) or aim to develop NOS views through classroom implementations (e.g. Akerson et al., 2000; Colak, 2009; Khishfe & Abd-El-Khalick, 2002; Khishfe, 2008). Some of these studies were summarized in the following paragraphs:

To explore ninth grade students' understanding of nature of science knowledge, Kilic et al. (2005) studied with 575 ninth grade students from four different types of school (vocational high school, super lycee, Anatolian high school, general high school). The sample included 295 girls and 280 boys. The Nature of Science Knowledge Scale developed by Rubba and Andersen (1978) was used to assess participants' NOS conceptions. The scale included 48 Likert-type items referring to six tenets of NOS. These tenets are amoral, creative, developmental, parsimonious, testable, and unified. The results illustrated that participants generally held a moderate understanding of scientific knowledge. The mean score on testable tenet was highest while parsimonious tenet had the lowest mean score. Regarding gender, girls held significantly more adequate understanding than boys about amoral and unified tenets. The result also showed that vocational high school students possessed more traditional views (i.e. less informed) than other school types.

Dogan and Abd-El-Khalick (2008) studied with 2087 Grade 10 students and 378 science teachers to explore the relationship between conceptions of nature of science and participants' gender, geographical region, and the socioeconomic status of their city and region; teacher disciplinary background, years of teaching experience, graduate degree, and type of teacher training program; and student family income, and parents' educational level. Participants' NOS views were measure through Views on Science Technology Society developed by Aikenhead, Ryan, and Desautels (1989). The result showed that both students and their teachers articulated similar conceptions of NOS which were mostly inadequate.

On the other hand, some researchers focused on how to develop nature of science views. For example, Akerson et al. (2000) assessed the effect of an explicit-reflective activity-based NOS instruction on pre-service teachers' understandings on targeted NOS aspects which included empirical, tentative, subjective, imaginative and creative, social and cultural NOS as well as the distinction between observation and inference, and the functions of and relationship between scientific theories and laws. A total of 50 students participated in the study. Half of them were undergraduate students in elementary education, and the rest were graduate students in elementary education. Undergraduate and graduate students were in the first year of their programs. Both almost had the similar science background based on the science credit hours they completed. The two groups of students attended two different sections of the elementary science methods courses. The two sections' students were required to do same readings, activities, and assignments. They were participated in hands-on/minds-on activities to explore key science concepts. The first six hours of the course were devoted to the 10 different activities to address the targeted NOS aspects explicitly. These activities were not embedded with content such as black box activities and followed by whole classroom discussions to explicitly refer to the NOS aspects. During discussions students were encouraged to reflect on NOS aspects and to relate them to other science-content and pedagogic topics. Data about NOS views were collected through open-ended questionnaires and semi-structured interviews before and after the course. Additional data sources were students' reflection papers and researcher log. The results revealed that participants' views on aspects which are tentative, creative and imaginative NOS, the distinction between observation and inference and the functions of and relationship between theories and laws developed more as compared to their views on subjective and social and cultural NOS. The authors concluded that explicit-reflective activity-based NOS instruction was effective in improving pre-service elementary teachers' NOS views with differential gains on some NOS aspects.

In another study, Khishfe (2008), studying with 18 seventh grade students, examined the effect of explicit inquiry-oriented approach embedded within science content on students' NOS views. The instruction lasted for 3 months. The teacher who taught the students was selected intentionally among other teachers since she showed substantial improvement in her NOS views after participating in a project. She also showed motivation and willingness to integrate NOS into her teaching. Students' NOS views were tracked before, during, and after the instruction through open-ended questionnaires developed by Khishfe and Abd-EL-Khalick (2002) with an interval time of one and a half month. Moreover semi-structured interviews were conducted with six selected students after administration of questionnaires to gain in-depth understanding of NOS views. The instruction took place for two 45-minute period for 12 weeks. The topics were the structure and living things, populations and ecosystems. Three inquiry-oriented activities about these topics integrated with explicit-reflective NOS instruction were conducted. Following each activity, the four aspects of NOS (i.e. the tentative, the empirical, the creative, and the distinction between observations and inferences) were discussed and students were allowed to reflect on them in association with the activity and science content. Students' NOS views were categorized as naive, uncategorized or informed. The results indicated that at the outset of the study most students possessed naive views regarding four aspects. During the instruction students changed their views into informed and intermediary views. At the end of the study they developed their views again into informed and intermediary levels. The authors concluded that these results were favoring the developmental model for NOS views.

Colak (2009) also examined the effect of explicit-reflective NOS instruction through inquiry-based activities on students' NOS concepts. Fourteen students in grades 5 to 8 who enrolled in an outreach program participated in the study. Within this program, students learned science subjects through inquiry-based, hands-on activities for six weeks on Saturdays till noon. Science subjects included physical science topics such as states of matter, electrolysis, and electricity. Every Saturday, first decontextualized NOS activities (e.g. black box or young and old women) were carried out. This was followed by contextualized NOS activities in which NOS aspects were embedded in inquiry-based activities. Data were collected through VNOS-D (Lederman & Khishfe, 2002) developed for elementary school students at the beginning and at the end of the outreach program. Among 14 students, 4 students were interviewed before and after the program. Participants' NOS views were categorized as irrelevant, inadequate, adequate, and informed. The results revealed important gains in students' NOS concepts regarding observation versus inference and tentative NOS. Moreover students holding inadequate views at the beginning of the study changed their views to adequate ones more easily than students holding adequate views at the beginning of the study. Students who already have adequate views at the outset of the study maintained their views without developing informed views. The authors discussed that explicit-reflective NOS instruction including both decontextualized and contextualized approach enabled students to improve their inadequate views.

Clough (2006) discussed that explicit-reflective NOS instruction may be either contextualized or decontextualized. He stated that NOS activities such as discrepant events, puzzle-solving activities (Clough, 1997), black-box activities (Lederman & Abd-El-Khalick, 1998) are examples of explicit-reflective decontextualized NOS instruction which aimed to engage students with important NOS ideas directly. This approach highlights the fundamental NOS aspects through isolating science content. Clough (2006) underlined the role of explicit-reflective decontextualized NOS instruction in making aware of students complex NOS views. However he criticized that explicit-reflective decontextualized NOS instruction may not meet students and teachers' perceptions of authentic science and may result in two alternative conceptions of NOS; one for authentic science views and one for decontextualized NOS activities. Clough (2006) further criticize that decontextualized NOS instruction can be perceived by teacher as an add-on material not related to the science content and wasting instructional time. On the other hand, explicit-reflective contextualized NOS instruction engage students with NOS issues embedded with science content and the development of scientific knowledge. Clough (2006) stated that "highly contextualizing the NOS means integrating historical and contemporary science examples that are tied to the fundamental ideas taught in particular science subjects” (p. 474). He further stated that:

> While teaching science content, seamlessly addressing the human side of science, epistemological and ontological assumptions underlying knowledge, difficulties in making sense of data, and justification for conclusions are crucial for explicitly and contextually addressing the NOS. A long advocated strategy to accomplish this has been integrating the history of science alongside the teaching of content (p. 478).

Clough (2006) emphasized the role of history of science in explicit-reflective contextualized NOS instruction. More recently Smith (2010) also emphasized that students are expected to reveal a deep understanding of NOS when the teacher and students investigate science concepts with contextualized HOS instruction. In other words Smith underscored the importance of contextualized NOS activities which use examples from the history of science. The development of NOS views through HOS is not a new argument. In the late 1990s, for example, Monk and Osborne (1997) recommended that science should be taught by integrating HOS to curriculum more often in order to help students to develop more adequate understanding of NOS. Howe and Rudge (2005) clarified that by integrating HOS to science lessons, students will be better able to reflect their understanding of NOS because HOS provide a good context for this reflection.

There are some studies showing that integrating history of science into science teaching enhances the students' understanding of NOS aspects. On the other hand, some studies indicate that the history of science has no or little effect on students' understanding of NOS aspects. Irwin (2000) used the history of science in teaching atomic theory. Using the development of atomic theory from Greeks to the present, it aimed to improve students' NOS views. In the study, two fourteen-year old groups having similar abilities and science background were involved. First group of students was introduced to the history of atomic theory while second group of students was thought atomic theory without emphasizing historical materials. The results revealed that the group taught by history of science showed a better understanding of scientific theory and tentative aspect of NOS.

Lin and Chen (2002) also studied the effects of teaching chemistry through HOS on student teachers' NOS perceptions. A quasi-experimental study was conducted to find out the differences between experimental and control group in their understanding of NOS views. Experimental group was consisted of the senior student teachers while the control group was comprised of junior student teachers in the same department. The results showed that the experimental group did better on the NOS questionnaire compared to the control group. The students in the experimental group improved their comprehensions in the NOS aspects; the nature of creativity, the theory based nature of scientific observations, and the functions of theories.

Abd-El-Khalick and Lederman (2000) wandered whether the HOS has any impact on students' NOS aspects. They studied with two groups. First group included 166 undergraduate and graduate students majoring in biological and general science and they enrolled in three HOS courses. Second group involved 15 pre-service secondary science teachers who enrolled in a science methods/practicum course. A majority of the participants did not receive any HOS instruction before and they completed science courses in different disciplines including biology and physics. Three HOS courses were "Studies in Scientific Controversy", "History of Science", and "Evolution and Modern Biology". The first course included case studies from the 17^{th} through 20^{th} centuries emphasizing the rational, psychological, and social characteristics of the natural sciences. The second course focuses on the interaction of scientific ideas with their social and cultural contexts. The last one focuses on the origin and development of Darwin's theory of evolution. All three HOS courses did not include an explicit approach to teaching NOS. The second group in science methods/practicum course focused on classroom management, instructional planning, traditional and alternative assessments, and models of teaching. The second group students received explicit NOS instruction through mostly generic activities. Some of the activities were content-embedded. Data were collected through open-ended questionnaire and semi-structured interviews. The results of the study documented that HOS instruction has little influence on students' understanding of NOS aspects. The authors suggested that instructors should explicitly guide students for NOS views while focusing on historical narratives. That is HOS should be equipped with explicit-reflective NOS instruction to result in development of NOS views. Similarly; Dass (2005) searched for the effect of HOS on students' NOS views and found small advance in students' NOS views.

Seker (2004), summarized before, also studied the HOS with the aim to change eighth grade students' NOS views. He aimed to make students aware of different scientific methods, tentative NOS, the role of inference in scientific investigations, and subjective NOS. Students' NOS views were assessed by the Perspectives on Scientific Epistemology survey. Historical ideas of force and motion units were presented to the students and they were encouraged to discuss their ideas. Aristotle's ideas and Strato's sand experiments were discussed to refer to the constant and changing velocity. Then Galileo's inclined-plane experiment was performed for the comprehension of the acceleration concept. In this experiment, students simulated Galileo's original experiment. The controversies between ideas of Galileo and Aristotle were utilized for discussions to highlight tentative NOS. The findings showed that students' ideas of scientific methods affected with HOS. Moreover they understood the role of inference in the scientific process.

Howe (2004) also utilized history of sickle-cell anemia to influence preservice elementary teachers' NOS views regarding the aspects which are the nature of scientific theories, tentative NOS, the difference between scientific theories and laws, the validity of observational method in science, and the subjective NOS. 81 students enrolled in the course *Life Science for Elementary Educators* participated in the study. Open-ended questionnaire was administered and semi-structure interviews were conducted to explore participants NOS views about targeted aspects before and after the implementation. Students were instructed about sickle cell anemia through explicit-reflective NOS instruction embedded with historical materials. Participants improved their understanding of some NOS aspects after the sickle cell anemia unit. The results showed that participants' NOS views in terms of the validity of observational methods and subjective NOS substantially changed when they explicitly and reflectively discussed NOS in a history focused unit.

Further studies were also conducted to explore the effect of history of science instruction in learning and improving nature of science views. Kim (2007) also explored the effect of teaching genetics with history of science providing students opportunities to write and reflect on NOS aspects. A quasi-experimental control group research design was utilized with two tenth grade biology classes. Both groups received the same instruction except experimental group was instructed through the integration of History of Genetics. Data were collected through View of Nature of Science-C form and also concept mapping for NOS terms. The results showed that after the instructions the experimental group showed significant changes in their NOS understandings when compared with the control group. The experimental group also performed better in defining NOS terms and constructing a concept map about NOS terms. The authors concluded that this study provided empirical evidence for improving NOS views through HOS instruction.

It is evident from the studies above that the effect of HOS instruction on the development of NOS views need further investigations with lower grade levels to come up with a more accurate picture of the issue. There are few studies which explored students' NOS views at grade six level (Akerson & Abd-El-Khalick, 2005) and there is a need to explore elementary level students' understandings of NOS to help them develop their current views (Akerson & Abd-El-Khalick, 2005; Smith, Maclin, Houghton, & Hennessey, 2000). Moreover there is a need for experimental studies to investigate the causal relationship between HOS and NOS. Therefore the result of this study is important to attain evidence of causality for the influence of HOS on NOS views.

CHAPTER III

METHODOLOGY

This study mainly investigated the relative effectiveness of history of science instruction and curriculum-oriented instruction on Grade 6 students' scientific literacy. This chapter described research design of the study, population and sample, variables, instruments, the treatments, ethical consideration, data analysis, and validity of the study.

3.1 Research Design

For the purpose of the study, *quasi-experimental* research design, a type of quantitative research methodology, was adopted. Frankel and Wallen (2003) stated that experimental research is one of most powerful research to test hypothesis for cause and effect relation between variables. In this study the effect of independent variable (i.e. two types of instruction) on multiple dependent variables (i.e. science process skills, understanding of circulatory system concepts, attitudes toward science, and NOS views) was investigated. It was aimed to check whether the effect of HOS instruction and curricular-oriented instruction differ with respect to these dependent variables across time.

This is a quasi-experimental research design because there was no way to assign participants randomly to the experimental and comparison groups. Accordingly, randomly selected four intact classes from Grade 6 participated in this study. Two classes were assigned randomly as experimental group while other two were assigned randomly as comparison group. The classes were instructed in a similar way that the current science curriculum offers for circulatory system topic. However, history of science was integrated into the curriculum-oriented instruction in experimental group. The effectiveness of history of science instruction over curriculum-oriented instruction was compared by means of pre, post and follow up measurements.

At the outset of the study, students' science process skills, understanding of human circulatory system concepts, attitudes toward science, and nature of science views were assessed in order to determine whether the groups differ from each other with respect to these variables. Then the experimental group received HOS instruction on the topic of circulatory system while comparison group followed curriculum-oriented instruction on the same topic. Just after the completion of the instructions, posttests were administered to the groups in order to evaluate the immediate effects of instructions on abovementioned variables. To assess the continuous effects of the treatments, follow-up tests were carried out 5 weeks after the completion of the treatments in terms of aforementioned variables. These variables were compared statistically to find out possible differences between groups. In addition to quantitative analysis of dependent variables, students' NOS views were analyzed qualitatively. The researcher was also interested in the difference within groups, so pretest, posttest and follow-up test results of each group compared separately. The variables were measured by means of Science Process Skills Test (SPST), Circulatory System Concepts Test (CSCT), Test of Science Related Attitudes (TOSRA), and Views on Nature of Science Elementary School Version (VNOS-E). In Table 3.1, the summary of the process and the sequence of administrations of the instruments were illustrated as an outline.

Table 3.1 Outline of the Design of the Study

	Experimental Groups	Comparison Groups
Pretests	SPST CSCT TOSRA VNOS-E	SPST CSCT TOSRA VNOS-E
Intervention	Teaching circulatory system concepts with HOS instruction	Teaching circulatory system concepts with curriculum-oriented instruction
Posttest	SPST CSCT TOSRA VNOS-E	SPST CSCT TOSRA VNOS-E
Five-week Interval	Engaging in curriculum-oriented instruction without HOS	Engaging in curriculum-oriented instruction without HOS
Follow-up Test	SPST CSCT TOSRA VNOS-E	SPST CSCT TOSRA VNOS-E

3.2 Population and Sample

The target population of this study included all 6^{th} grade elementary students attending public schools in Ankara. The accessible population was all 6^{th} grades elementary students in the public schools of Cankaya district.

The participants of the study were selected based on convenient sampling procedure because of its advantages in reducing time and energy, and its cost effectiveness. As mentioned above two classes participated in the study as experimental group and two classes as a comparison group and composed of 6^{th} grade students attending a public school located in Ankara. Science courses of each group had been instructed by the same teacher since the opening of the fall semester. This study was conducted during 2011-2012 spring semester.

The subjects of this study consisted of 95 students (47 boys and 48 girls) with a mean age of 12.08. Among these students 51 (26 boys and 25 girls) were in the experimental group while 44 (21 boys and 23girls) were in the comparison group. Accordingly, ratios of boys and girls in the study and within each group were comparable. Students ranged in age from 12 to 13. The mean age of the students in the experimental group was 12.06 while that of comparison group was 12.12. The mean science report card grade of previous semester was 3.47 for experimental group students and 3.54 for comparison group students over 5.00.

Around 50 % of students in both experimental and comparison groups were from families with 2 children. Majority of students' parents had undergraduate education and below. More than 90 % of the fathers in both groups were employed. In Table 3.2, detailed comparison of the groups regarding background characteristics were provided. It is evident that students in experimental and comparison groups were comparable in terms of their background characteristics.

Table 3.2 Background Characteristics of Students

	Experimental Group		**Comparison Group**	
	Frequency	*Percent (%)*	*Frequency*	*Percent (%)*
GEND				
Girls	25	49.0	23	52.2
Boys	26	51.0	21	47.8
CHILD				
1.00	8	15.7	8	18.2
2.00	30	58.8	22	50.0
3.00	12	23.5	10	22.7
4.00 or more	1	2.0	4	9.1
MES				
Employed	31	60.8	23	52.3
Unemployed	20	39.2	21	47.7
FES				
Employed	48	94.1	43	97.7
Unemployed	3	5.9	1	2.3
MEL				
Primary School	2	3.9	3	6.8
Secondary School	4	7.8	8	18.2
High School	15	29.4	11	25.0
Undergraduate	27	52.9	17	38.6
Graduate	3	5.9	4	9.1
Non-schooling	0	0	1	2.3
FEL				
Primary School	1	2.0	2	4.5
Secondary School	2	3.9	3	6.8
High School	16	31.4	14	31.8
Undergraduate	22	43.1	20	45.5
Graduate	10	19.6	5	11.4
Non-schooling	0	0	0	0

Table 3.2 (Cont.)	Experimental Group		Comparison Group	
	Frequency	*Percent (%)*	*Frequency*	*Percent (%)*
READI				
0-10 books	5	9.8	4	9.1
11-25 books	12	23.5	13	29.5
26-100 books	18	35.3	14	31.8
101-200 books	11	21.6	8	18.2
More than 200 books	5	9.8	5	11.4
NEWS				
Never	8	15.7	7	15.9
Sometimes	30	58.8	27	61.4
Daily	13	25.5	10	22.7
ROOM				
Have a study room	42	82.4	34	77.3
Do not have a study room	9	17.6	10	22.7
COMP				
Have computer	40	78.4	39	88.6
Do not have computer	11	21.6	5	11.4
INTER				
Have internet connection	28	54.9	26	59.1
Do not have internet connection	23	45.1	18	40.9

Note: *The abbreviation in Table 3.2 means: gender (GEND), number of children in the family (CHILD), mother's employment status (MES), father's employment status (FES), mother's education level (MEL), father's education level (FEL), number of reading materials at home (READI), frequency of buying newspaper (NEWS), having a study room (ROOM), having a computer (COMP), and having an internet connection (INTER).*

3.3 Variables

In this study there are five major variables. In order to make clear distinctions between variables they were categorize into two main categories as independent variable and dependent variables.

3.3.1 Independent Variables

In the study, type of instructions was the manipulated variable and labeled as the independent variable. Two types of the instruction compared in terms of their effectiveness on the dependent variables were history of science instruction and curriculum-oriented instruction.

3.3.2 Dependent Variable

The study included four dependent variables namely, science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science views. These four dependent variables, as the most commonly suggested sub-dimensions of scientific literacy, were drawn from the relevant literature.

3.4 Instruments

Four instruments were used throughout the study. Each of these four instruments was used three times as pretest, post test and follow-up test during the course of the study. These instruments were: Science Process Skills Test (SPST); Circulatory System Concepts Test (CSCT); Test of Science-Related Attitudes (TOSRA); and Views of Nature of Science Elementary School Version (VNOS-E). In the following four sections detailed information was given about these instruments.

3.4.1 Science Process Skills Test (SPST)

The SPST was originally developed by Burns, Okey, and Wise (1985). This 36 item multiple-choice test aimed to measure the science process skills of students in terms of identifying variables (12 items), stating the hypotheses (9 items), operationally defining (6 items), graphing and interpreting data (6 items), designing investigations (3 items). Burns at al. (1985) evaluated test results by giving 1 point to each correctly answered questions and 0 point to each wrongly or unanswered questions. Therefore, the possible scores a student can get from the test changes from 0 to 36. The Cronbach's alpha coefficient was reported as .86 for the whole test. The sub-scale reliabilities found by Burns et al. (1985) were presented in Table 3.3.

Table 3.3 Reliability Coefficient of Subtest of SPST

	Identifying Variables	Operationally Defining	Stating Hypothesis	Graphing and Interpreting Data	Designing Investigations
Cronbach's Alpha	.57	.62	.65	.64	.49

The developers of the instrument also reported mean item difficulty indices as .53 ranging from .11 to .64 and mean discrimination indices as .35 ranging from .15 to .87. This test has been developed based on the idea that even though it is possible to measure students' science process skills via observation, it will lead to very limited and sometimes intuitive measures. Burns et al. (1985) reported that it is a valid and reliable test to measure accurately students' science process skills. The test was firstly translated and validated into Turkish by Geban, Askar and Ozkan (1992) with 200 Grade 9 students. The reliability coefficient was reported as .81 for the whole test. Later, Can (2008) administered this version to 227 seventh grade students. After reliability and validity analyses, 26 items having item discrimination above .20 were retained. Can (2008) reported the total reliability coefficient of the test as .80. In the current study the 26-item version of SPST validated by Can (2008) was used for two reasons: First, validity of this test has been ensured with younger students (i.e. Grade7). Second, it requires less time to complete for younger students. Therefore, 26-item version of was more convenient for the sake of administration and used in this study.

Table 3.4 shows related science process skills and objectives measured in the original test with total number of items in both versions.

Table 3.4 Science Process Skills, Objectives and Total Number of Items in Science Process Skills Test

		Total Number of Items	
Skills	Objectives	Original Version (Burns et al., 1985)	Turkish Version (Can, 2008)
Identifying Variables	Given a description of an investigation, identify suitable operational definitions for the variables.	12	11
Operationally Defining	Given a description of an investigation, identify the manipulated, responding and controlled variables.	6	3
Stating Hypotheses	Given a description of variables involved in an investigation, select a testable hypothesis.	9	6
Graphing and Interpreting Data	Given a description of an investigation and obtained data, identify a graph that represents the data and describe the relationship between the variables.	6	3
Designing Investigations	Given a hypothesis, select a suitable design for an investigation to	3	3

In the current study, before administering the instrument to the sample, the researcher further reviewed the entire sets of 26 questions interviewing with eight students from six grade level in attempt to ensure face validity of the instrument. During this process the following 3 questions were asked to students: Does the question/choice have any word/term that you are not familiar with? Did you understand the question/item? Can you explain what the question asks in your own word? Through the interviews, it was noticed that several students were not familiar with some words used in Turkish version of the test. Therefore the alternative wording was introduced without altering the structure and the meaning of sentence. After agreeing on the wording and being sure that the students understand the question, necessary changes were made on wording. After negotiating with the teacher of the classes, the test was ready for the administration.

In the next process the test has been administered to 148 students at 6^{th} grade level at Cankaya district of Ankara. In total Cronbach's alpha coefficient for 6^{th} grade students was found as .79 which refers to a high reliability. Also sub-scale reliabilities found as follows: .59 for identifying variables; .61 for operationally defining; .58 for stating hypothesis; .62 for graphing and interpreting data; and .56 for designing investigations.

After obtaining concrete evidence for the appropriateness of the test for the level of participant in this study, it was ready for the administration (see Appendix A). To remind, students science process skills were evaluated over the total score students get from SPST as suggested by Burns et al. (1985). Actually, other researcher followed the same process of evaluation in Turkish context (e.g. Can, 2008; Kanli & Yagbasan, 2008; Tezcan & Salmaz). In fact this test had been used three times as pretest, posttest and follow-up test during the study. The total reliabilities were found as .81 at Time 1; .83 at Time 2; and .78 at Time 3. Putting it all together, it is safe to come up with the conclusion that the instrument was reliable for the sample of this study.

3.4.2 Circulatory System Concepts Test (CSCT)

This test was developed by the researcher. The purpose of developing CSCT was to evaluate sixth grade level students' understanding of human circulatory system concepts in terms of learning objectives defined in current science curriculum and teacher guide book.

In the first step, table of specification was constructed based on the curriculum objectives (see Appendix S for the objectives). While constructing table of specification, *cognitive domain of educational objectives* (Bloom, 1956) were used. In this taxonomy, there were six major categories. From simplest to most complex these categories included: knowledge, comprehension, application, analysis, synthesis, and evaluation. Bloom (1956) stated that in normal conditions one should be master at former one before improve to the next one. In other words there is a hierarchy between the categories. Table 3.5 illustrates the table of specification used to develop the CSCT.

Table 3.5 Table of Specification for Circulatory System Concepts Test

	Number of Learning Objectives					
Subject Matter	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Structure and function of the hearth	1	1		4	3	1
Blood vessels	2	2			1	2
Constituents of blood and blood types	1	2	2	2		1
Pulmonary and systemic circulation					2	
Lymphatic system	2					
Circulatory system issues		1				2

After creating the table of specification, the researcher created a pool of items considering it. As a result 32 multiple choice questions with four choices were developed. In the next stage two experts in elementary science education department analyzed the stem, the correct answer, and the distracters one by one in terms of language, level of difficulty, clearness of items, suitability with objectives, relevance of materials with topic, keywords in distracters, and plausibility of wording. After taking the suggestions of experts, required modifications have been made on the test. In the next stage each questions has been evaluated with an expert medical doctor to eliminate any deficient knowledge in the test. Some part of the test modified with the suggestion of the medical doctor. This form of the test has been negotiated with the experts again and consensus among the team has been arrived. In the following step a Turkish language expert evaluated the test in terms of ambiguity in language, punctuation and wording. After arriving at a consensus with the medical doctor, experts and Turkish language experts the questions have been interviewed with 4 students in 6^{th} grade level just after they took the test. In this process it was aimed to find out the appropriate time for taking the test and whether the test includes any vocabulary that is unfamiliar to students, whether it is understandable by students, and whether students understand what is meant in the test. The interviewed showed that the test is appropriate for the level of 6^{th} grade students. It has been also found that the test takes 30-35 minutes for 6^{th}grade students to complete. The final form of CSCT (see Appendix B) was piloted with 135 students from 7^{th} grade level in a public school in Cankaya region where the actual study has been carried out. The reason why the final form administered to Grade 7 students instead of Grade 6 was that they were familiar with the circulatory system. Indeed, the test has been developed at the fall semester but circulatory system has been taught to 6^{th} graders at spring semester. The reliability of the test has been found as .74. According to Gronlund and Linn (1990) this is an acceptable reliability for a test.

3.4.3 Test of Science Related Attitudes (TOSRA)

The original version of TOSRA was developed by Fraser (1978). TOSRA consists of 70 Likert-type items in seven subscales. These subscales are named as social implications of science, normality of scientists, attitude to scientific inquiry, adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, and career interest in science (Fraser, 1978). Each subscale includes 10 items. The TOSRA has 5-point Likert type response format, ranging from strongly disagree (1) to strongly agree (5). Table 3.6 illustrates sample items for each of the subscales in TOSRA.

Table 3.6 Subscales and Sample Items of TOSRA

Subscales	Sample item
Social Implications of Science	Money spent on science is well worth spending.
Normality of Scientists	Scientists usually like to go to their laboratories when they have a day off.
Attitude to Scientific Inquiry	I would prefer to find out why something happens by doing an experiment than by being told.
Adoption of Scientific Attitudes	I enjoy reading about things which disagree with my previous ideas.
Enjoyment of Science Lessons	Science lessons are fun.
Leisure Interest in Science	I would like to belong to a science club.
Career Interest in Science	I would dislike being a scientist after I leave school.

Fraser (1978) underlined that TOSRA has been developed based on Klopfer's six classification category on attitude and interest. In his prominent writing, Klopfer (1971) clarified these six categories as follows: Behaviors which manifest favorable attitude toward science and scientist; acceptance of scientific inquiry as a way of thought; adoption of scientific attitudes; enjoyment of science learning experiences; development of interest in science and science-related activities; development of interest in pursuing a career in science or science-related work.

Behaviors which manifest favorable attitude toward science and scientist: Klopfer (1971) contended that whenever students think science as nasty attempt or scientist as disregarded "eggheads", then a non-favorable attitude are expected from them. He also agreed that all science teachers want their students to exhibit positive attitude toward both science and scientist. Fraser (1978) constituted the first two sub-dimensions (Social Implications of Science, and Normality of Scientists) of TOSRA based on this classification. However, this classification did not explicitly refer to "Normality of Scientists" at all in the original writing of Klopfer. It just referred to the general attitude of students toward science and scientist. The term "general attitude toward science" is too broad to be one of the sub-dimensions of the test. In fact attitude toward science has been investigated by the collective sub-dimensions of TOSRA. Besides, for the purpose of the study participants understanding about scientists, which is called "normality of scientist" in original TOSRA, has been measured through VNOS-E; because it has been expected to give the researcher in-depth information about it overall. Hence, these two dimensions have been put out of the TOSRA in this study so that students could finish the test at one class-hour, and the result can be interpreted more clearly.

Acceptance of scientific inquiry as a way of thought: The third dimension of TOSRA, named as "Attitude to Scientific Inquiry" has been developed by Fraser based on this category. According to Klopfer this dimension of attitude connected to students' attitude toward inquiry of science. Klopfer (1971) stated that:

> It is entirely possible that a student could engage in the process of scientific inquiry even though he viewed them merely as school exercises; that he could observe, measure, hypothesize, formulate generalization, and devise and test theoretical models without any sense

> that these activities are personally valuable to him and without feeling that they might be valid guidelines for his own thinking (p. 577).

As a researcher my contention is that such student may have misconception about the basic tenets of nature of science. It is very likely that such student may think science as a discipline in which answers are found through systematic inquiries only. According to Hanuscin, Phillipson, and Pareja (2005) this kind of thought is precursor of naïve views about nature of science. It is not known whether such student might or might not have misconception about the nature of science, to be on the safer side this sub-dimension of TOSRA has also been excluded from the test.

Adoption of scientific attitudes: This subcategory offered by Klopfer was the only one used by Fraser without changing its name as the forth sub-dimension of TOSRA. Klopfer advocated that scientists are affected by scientific community; therefore, they try to be as “self-critical”, “open-minded”, and “honest” as they can do. Most importantly the students are expected to imitate those characteristics when they are conducting inquiries (1971). In this sense this sub-dimension implicitly refers to socio-cultural aspect of NOS. Therefore it is within the aim of this study to evaluate the change (or consistency) on this sub-dimension throughout the course of the study through two different types of instructions.

Enjoyment of science learning experiences: This sub-category is related to the school science learning experience. Klopfer (1971) expressed the presence of psychological evidence that when the students have pleasure in learning science at schools, their learning become more and better; and they also retain the knowledge longer. By conducting this study, one of the main rationales by collecting follow-up data from students was to inspect whether one of the method yield better retain on DVs. For this reason, this sub-dimension of the test is expected to provide precious information about the sample. Fraser (1978) named this dimension as “Enjoyment of Science Lesson” in TOSRA development process as the fifth sub-dimension.

Development of interest in science and science-related activities: Klopfer examined this category under two different but related heading. The first one is related to students’ informal (out-of school) activities carried out by themselves. Klopfer gave "collecting butterflies", "experimenting with hybrid flowers" examples to this category. The second one is related to the awareness of students toward current scientific development and science-society interaction. "Circulating for a petition for preservation of a wildlife refuge" and "watching a television program on cancer research" were among two specific examples put forward by Klopfer (1971). Klopfer (1971) concluded that these two categories are about interest of scientifically literate person. In this study, scientific literacy is of interest by the collective dependent variables. Consequently this sub-dimension, so-called “Leisure Interest in Science” by Fraser as the sixth sub-dimension of TOSRA, was another interest of this study.

Development of interest in pursuing a career in science or science-related work: In the last category of Klopfer's classification of attitudes and interest toward science, he claimed that small percent of total students in a class has tendency toward science or science-related careers. Although it is not stated explicitly what Klopfer mean stating "science or science-related career", what he asserted is really debatable. If he mean pure physics, chemistry or biology, he may be right. But it has to be kept in mind that from surgeon to engineering; from archeologist to electrician; from pilot to dancer, a great deal of the job is related to science to some extent. Although, not to be on the same mind with Klopfer about his generalization toward the ratio of students having aptitude toward science related career, what he expressed, saying that their interest should be improved, is worth supporting. Fraser (1978) has been constituted the last sub-dimension of TOSRA, specifically "Career Interest in Science", based on this category. This dimension has also been one of the pursuits of this study.

Accordingly, within the scope of the present study, only adoption of scientific attitudes, enjoyment of science lessons, leisure interest in science, career interest in science sub-scales of the TOSRA was used to assess participants' attitude toward science.

Fraser pilot tested the TOSRA with 1,337 students including 44 classes from 11 different schools in the Sydney metropolitan area. Actually the test was validated for Grade 7 (N = 340), 8 (N = 335), 9 (N = 338), and 10 (N = 324) through the pilot study. In this sense the sample size for each group was fairly homogenous. It has also been expressed that the number of boys and girls were almost equal in each grade level.

Fraser (1978) reported reliabilities of subscales ranging from .66 to .93 for seven grades; .64 to .92 for eight grades; .69 to .92 for ninth grades; and .67 to .93 for tenth grades with a means of .82; .80; .81; .84 for each class respectively. Reliability statistics of each subscale was shown at Table 3.7 for each grade level.

Table 3.7 Reliability Coefficient of Subtest of TOSRA

	Cronbach Alpha Reliability across Grade Level			
Subscale	Grade 7	Grade 8	Grade 9	Grade 10
Social Implications of Science	0.81	0.82	0.75	0.82
Normality of Scientists	0.72	0.70	0.72	0.78
Attitude to Scientific Inquiry	0.81	0.82	0.81	0.86
Adoption of Scientific Attitudes	0.66	0.64	0.69	0.67
Enjoyment of Science Lessons	0.93	0.92	0.92	0.93
Leisure Interest in Science	0.88	0.85	0.87	0.89
Career Interest in Science	0.90	0.88	0.88	0.91

Telli, Cakiroglu, & Rakici (2003) translated TOSRA into Turkish and pilot tested with 399 students from 11th grade level in the fall semester of 2003. After conducting first pilot study and making necessary changes based on factor analysis, they again piloted the test to 1983 students at 9th and 10th grade level from nine different schools. In the second study Telli at al. (2003) reported reliability coefficients for each subscale ranging from .62 to .85. In this sense, it is possible to say that the sub-dimension of TOSRA has sufficient internal reliability for the Turkish sample.

In this study, the items of TOSRA were interviewed with 8 students from Grade 6. During this process, the same three questions used during validation of SPST were asked to the students (see section 3.4.1). The interview indicated that students could comprehend the questions. Next, the instrument was administered to 217 Grade 6 students. As explained before, the items which represents three subscale of TOSRA was eliminated from the instrument. Therefore, this version of TOSRA consisted of four factors, namely Adoption of Scientific Attitudes, Enjoyment of Science Lessons, Leisure Interest in Science, and Career Interest in Science. The total of 40 items were analyzed to explore how well these items fit with underlying structure of TOSRA with the sample of grade six students. For this purpose, these dimensions were subjected to factor analysis using SPSS. Before running the test, related assumptions were tested. It was suggested that there should be at least five cases for each item. There were 40 items in TOSRA therefore a sample of 200 students were needed (40 * 5 = 200). There were 217 students who completed the instrument in pilot study. Therefore the assumption of sample size were sufficient enough for factor analysis. Also, Kaiser-Meyer-Olkin measure of sampling adequacy was .89 and Bartlett's test of sphericity was statistically significant, χ^2 (780) = 4439.01, $p < .0005$. These two statistics were also evident that the data was suitable for factor analysis. Using Kaiser's criterion, there were ten factors with eigenvalue grater than 1. The screeplot (see Figure 3.1), however, indicated that there is a clear change between first and second components and first component explains quite big percent of the variance (34.41 %) when compared to other components. In other words, screeplot indicated one factor. On the other hand, parallel analysis using Monte Carlo PCA (Watkins, 2000) suggested to extract three factors. Lastly, component matrix table (see Table 3.8) indicated that almost all items (except 5 and 29) loaded strongly (above .4) to only one factors. This result indicated that the four-factor structure of the TOSRA is not well-suited with this sample and one-factor structure is more appropriate by eliminating item 5 and 29. After removing item 5 and 29, first component explained 36.18 % of total variance by itself. The results of this analysis supported to use of one-factor and named as "Attitudes toward Science".

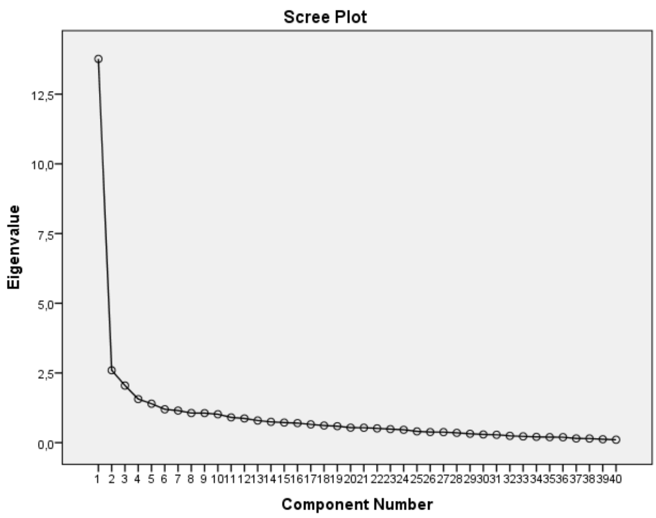

Figure 3.1 Screeplot for the Determination of Number of Factors Retained in TOSRA

Cronbach's alpha coefficient for the whole test was found to be .88 which refers to a high reliability. These evidence provided that TOSRA is appropriate for Grade 6 students.

In this study TOSRA (see Appendix C) was administered to the sample of the study three times; pretest, posttest and follow-up test. The total reliability coefficients were found to be .92, .94, and .93 for the combined subtests at pretest, posttest, and follow-up measurement respectively. These results show that the TOSRA has very good internal consistency with the sample of the study. It provided evidence to infer that participants' answers were consistent throughout the testing.

Table 3.8 Component Matrix Displaying the Loadings of Each Item on TOSRA

	Component									
	1	2	3	4	5	6	7	8	9	10
Item 26	.79									
Item 34	.74									
Item 11	.73									
Item 14	.73									
Item 22	.72									
Item 21	.72									
Item 2	.71		-.31							
Item 19	.70									
Item 25	.70									
Item 13	.69						-.33			
Item 9	.67	-.36								
Item 35	.67									
Item 33	.66				.35					
Item 20	.66									
Item 18	.62									
Item 15	.62	.34				-.32				
Item 28	.61		.37							
Item 17	.58									.50
Item 10	.58				-.43				-.31	
Item 6	.58	.31								
Item 23	.57			-.31						
Item 38	.56		-.32							-.40
Item 32	.56			.33						.31
Item 8	.56		.52							
Item 36	.56	.39	.36							
Item 24	.55				.31				-.38	
Item 30	.55			.41						
Item 31	.54	.33								
Item 27	.53		.40	-.34						
Item 37	.52	.30	-.32							
Item 7	.51									
Item 3	.48				-.36					
Item 39	.46	.43		-.31						
Item 16	.45		.32							
Item 12	.44	.35	.35							
Item 40	.48		.50					.37		
Item 4	.32		.32	.45		-.38			.36	
Item 29		.45			-.31	.54				
Item 5		.45					.57			
Item 1	.35	-.32					.44		.34	

3.4.4 Views of Nature of Science Elementary School Version (VNOS-E)

In order to measure students' nature of science views VNOS-E was utilized in this study. VNOS-E was developed original by Lederman & Ko (2004) with elementary level teacher (*N* = 10) and their students. VNOS-E was used in this study because it was proper for elementary level students in terms of "developmental appropriateness" and "language" (Lederman 2007). It is an open-ended instrument consisting of 7 items. VNOS-E has been developed to assess basically five aspects of NOS: Tentative, Empirical, Subjective, Creativity, and Inferential NOS (Meyer & Crawford, 2011; Parker, 2010). VNOS-E was translated into Turkish and validated by Dogan, Cakiroglu, Cavus and Bilican (2010). In this study VNOS-E (see Appendix D), as other instruments, was administered both groups three time during the course of the study to assess participants' pre, post, and follow-up NOS views.

3.5 Treatments

This study explored the influence of history of science instruction compared with curriculum-oriented instruction on 6th grade students' attitudes toward science, science process skills, understanding of circulatory system concepts, and nature of science views. In the study the former group was referred as experimental group, and the latter was referred as comparison group. To be consistent throughout this study these terms were used mostly. In line with the purpose, experimental group was engaged in HOS activities, discussed explicitly and reflectively referring to one or more specific NOS aspects, and then they followed content-specific activities. The comparison group was engaged in the same content-specific activities but without integration of HOS. The researcher implemented the treatment in the experimental group for some reason. First, the teacher in this study indicated that he could not able to succeed in history of science instruction due to his incompetence about it. Monk and Osborne (1997) stated that many science teachers could not incorporate HOS with the fear of losing their authority in the classroom. They added that inability of establishing relationship between HOS and science content or having low self-confidence interfere with their capability of incorporating HOS into classrooms. Also, some studies supported that even if classroom teachers have adequate NOS understanding they are not able to teach NOS aspects to their students or they are not motivated to teach it (Akerson& Abd-El-Khalick, 2003; Akerson, & Hanuscin, 2007; Bell et al., 2000; Hodson, 1993; Lederman, 1999). The comparison group was instructed by their regular science teacher. In order to prevent implementation threat, the teacher and the researcher met before each class and prepared lesson plan for the topic. The teacher and researcher followed the same sequence and carried out same activities for the topic as much as possible. Moreover the teacher and the researcher observed each other in order to ensure that each group has followed the previously prepared lesson plan. At the end of each course the researcher and the teacher negotiated the correspondence between what they implemented in both groups. Also they discussed the congruency between planned and enacted curriculum after each class. To conclude researcher and the teacher provided fairly similar content-specific activities in experimental and comparison group.

Before the treatment, the researcher made a four-week preliminary effort especially to remedy innovation threat to internal validity. During the first week of these preliminary efforts the researcher observed all four classrooms and tried to learn some functional information such as names of students, the teacher's way of teaching, and the teacher's classroom management strategies. For the duration of remaining three weeks the researcher instructed the experimental group based on the current science and technology curriculum without any reference to HOS. At the same time the teacher instructed the comparison group during this three-week period. Throughout this timeframe the teacher and the researcher observed each other to optimize the close alignment in classroom practices between two. Also, during the third and fourth week of preliminary part the pretests were administered in both groups. During this four-week preliminary sessions, researcher had chance to be familiar with the students; observe classroom rules and routines; habituate the classroom environment; learn the way students communicate with the teacher and each other; and above all align the way of teaching between the researcher and the teacher.

After four-week preliminary efforts, the treatment was implemented in both groups. The participants in both groups engaged in same set of five activities. All of these activities were based on the activities suggested in national curriculum. But some activities were modified in such a way that nature of science aspects were highlighted better. Also some activities were added to engage students more on the topic by negotiating with classroom teacher. These activities were described in detailed in the following part. A summary of the activities conducted in experimental and comparison group and their purpose were given sequentially in Table 3.9.

Table 3.9 Sequence and Purpose of Activities in Experimental and Comparison Groups

Experimental Group		Comparison Group	
Activities	Purpose	Activities	Purpose
KWL chart	• activating students' prior knowledge • having information about what the students want to know • providing a summary of what is learned • collecting evidence to develop VNOS-E rubric	*KWL chart*	• activating students' prior knowledge • having information about what the students want to know • providing a summary of what is learned
Draw a scientist	• investigating group's perception of scientists	*Draw a scientist*	• investigating group's perception of scientists
Historical short story 1	• illustrating how a topic, specifically heart, in science was understood differently in different societies and by different scientists • showing that scientific knowledge is subject to change	*Revision of previous topics (Force) and solving problem*	• balancing the time
Structure and the function of the heart	• investigating the structure and the function of the heart • making observation and drawing inference • demonstrating the crucial distinction between observation and inference • understanding the subjective or theory-laden nature of science	*Structure and the function of the heart*	• investigating the structure and the function of the heart • making observation and drawing inference
Historical short story 2	• understanding the empirical-based nature of science • showing how different scientists draw different conclusions by looking at the same data or observing the same thing	*Revision of previous topics (Motion) and solving problems*	• balancing the time

Table 3. 9 (Continued)

Experimental Group		Comparison Group	
Activities	Purpose	Activities	Purpose

Constituents of blood	• showing that blood consists of plasma and cells
	• developing science process skills of
	  ○ observing
	  ○ communicating
	  ○ inferring
		Constituents of blood	• showing that blood consists of plasma and cells
			• developing following science process skills
			  ○ observing
			  ○ communicating
			  ○ inferring

Historical short story 3	• paying attention to some common fallacies in science:
	  ○ all scientists follow a single scientific method
	  ○ scientific knowledge is objective
	  ○ scientific knowledge does not change
	• underlying that creativity and imagination play role in the development of scientific knowledge
	• seeking empirical evidence in nature makes science unique.
		Revision of previous topics (Elements and Compounds) and solving problem	• balancing the time

Pulmonary circulation and systemic circulation	• comparing the types and the functions of blood vessels
	• comparing and establishing relationship between pulmonary and systemic circulation
	• visualizing the path of blood in pulmonary and systemic circulation
	• highlighting some aspect of NOS:
	  ○ empirically-based
	  ○ subjective
	  ○ creative and imaginative
		Pulmonary circulation and systemic circulation	• comparing the types and the functions of blood vessels
			• comparing and establishing relationship between pulmonary and systemic circulation
			• visualizing the path of blood in pulmonary and systemic circulation

Table 3. 9 (Continued)

Experimental Group		Comparison Group	
Activities	Purpose	Activities	Purpose
Blood Transfusion Timeline	• demonstrating the tentative nature of science • emphasizing the key role of observation in science • stressing imaginative and creative nature of science • showing the effect of subjectivity in science	*Revision of previous topics (Chemical Change) solving problem*	• balancing the time

Blood types	• categorizing main human blood types
	• stressing the essence of blood transfusion
	• developing science process skills of
	  ○ collecting data
	  ○ graphing
	  ○ interpreting the graph
	  ○ communicating
		Blood types	• categorizing main human blood types
			• stressing the essence of blood transfusion
			• developing science process skills of
			  ○ collecting data
			  ○ graphing
			  ○ interpreting the graph
			  ○ communicating

William Harvey's Experiments	• highlighting some aspect of NOS:
	  ○ *empirically-based*
	  ○ *creative* and *imaginative*
		Revision of previous topics and solving questions	• balancing the engagement time

• **Table 3. 9** (Continued)

Experimental Group		Comparison Group	
Activities	Purpose	Activities	Purpose
Blood donation	• developing a common sense to blood donation • raising awareness to benefits of blood donation • defining lymphatic circulation, and function of the lymph • demonstrating the location of lymphatic vessels and lymph nodes on human body • giving value to circulatory system health	*Blood donation*	• developing a common sense to blood donation • raising awareness to benefits of blood donation to hospitals, donors, recipients and also society • defining lymphatic circulation, and function of the lymph • demonstrating the location of lymphatic vessels and lymph nodes on human body • giving value to circulatory system health

As seen in Table 3.9, before each activity only experimental group was engaged in historical materials. Each historical material was introduced in the experimental group in the following four phase: experiencing historical material; engaging in probing question; whole class discussion; and creating generalization.

1. *Experiencing Historical Material*: In this phase of the implementation students were engaged in a specific historical document. Students studied the material either individually or as a small group. In this phase researcher observed students in order to avoid likely off-task behavior.
2. *Engaging in Probing Questions*: After students experienced the historical material they were given handouts. In these handouts there were probing questions about related historical material. The goal of this phase was to make them prepared for the next phase and organize their thoughts with reference to historical materials at hand.
3. *Whole Class Discussion*: In this phase the aim was to provide students an open space to share their opinions with historical evidences. Students presented their ideas, elaborated others thoughts, challenged with counterclaims and provided evidence from historical material. In this phase researcher actively monitored students to ensure that each students actively participated to discussion as much as possible; they established multiple interpretations (both proponents and opponents of an idea); and they make explicit connection between the historical material and specific NOS aspect.

4. *Creating Generalization*: In the last phase students were guided to generalize the central historical material to the complex epistemology of science. In this phase it was intended that students develop an appreciation of nature of science through making connections between the specific historical activity and scientific enterprise.

The Presentation of Activities

At the beginning of the treatment KWL chart, which was developed first by Ogle (1986), was distributed to each student in both groups in order to use throughout the treatment. Ogle stated that step “K” is to access what students know; step “W” is to determine what the students want to learn; and step “L” is to recall what students learned (1986). Ogle argued that evoking students’ prior knowledge generally was neglected during teaching although it is important for comprehension of the new knowledge. For the simplicity of this graphical organizer in terms of activating students’ prior knowledge and providing a summary of what is learned, the researcher had modified it by adding some pictures and made it lively for students so that students fill it without getting bored (see Appendix E). In terms of prior knowledge, students had already learned about the circulation of blood in the vessels and the function of heart as pumping blood to the whole body in 4^{th} grade level (MoNE, 2011). The investigation of students’ written responses under “K” section showed that students in both groups retained their prior knowledge obtained in 4^{th} grade. This chart was not used directly in the data analysis as a data source. The only exception to this was its use in providing trustworthiness of VNOS-E rubric because experimental group students referred to nature of science views when they wrote about what they learned during the activities. Other than this, the chart helped students recall their previous knowledge on circulatory system and recognize the new information learned. For example, the first activity was about the heart and its structure. Before activity, students wrote down what they know about heart and its structure under the "K" section of the chart. They continued with what they want to learn more about heart in this activity and noted them under the "W" section. At the end of the activity, they filled the "L" section with what they learned from this activity. Some examples of KWL charts prepared by the students were given in Appendix E.

In order to investigate whether two group's perception of scientists differed prior to implementation, students were asked to draw a scientist. The drawing papers were adapted from Fralick, Kearn, Thompson, and Lyons (2009). Sample students' drawings were provided in Appendix F for both groups. The investigation of students' drawings showed similar patterns in both groups. They draw scientists as male with eyeglasses who carries out experiments in laboratory. Some of them added dangerous signs and explosion figures to the laboratory environment. These drawings refer to stereotypical images of scientists among students in both groups. This was important for the aim of the study since both groups hold similar views of scientists. This may provide evidence for that the difference between groups' views of nature of science in post and follow-up tests did not result from their prior perceptions of scientists.

After this point the activities conducted in experimental and comparison group were explained. Both groups completed same content-specific activities as mentioned before. Before each activity only experimental group was engaged in historical materials while comparison group was engaged in activities different than circulatory system to equalize the engagement time in content-specific activities. For example comparison group reviewed previous topics and solved questions about them. Beyond this point, the sequence of activities was given according to the experimental group. When activities were presented the differences (historical materials and nature of science discussions) in experimental group were specified within the activities.

Historical short story 1 (Only in Experimental Group): This historical short story was adapted from Azizi, Nayernouri, and Azizi (2008); Gross (1995); Malomo, Idowu and Osuagwu (2006); and “The history of the heart (n.d.)”. This story was intended to illustrate how a topic, specifically heart, in science was understood differently in different societies and by different scientists. By means of this “story” students were expected to be aware of the misconception that scientific knowledge is definite and does not change.

At the beginning of the class, this first historical short story was distributed to students as a handout. In this handout, the historical information about heart was introduced to students; for example ancient Indians believed human heart to be the center of nervous system; Empedocles claimed the function of heart as the core of life-giving heat to the human body; Hippocrates asserted that liver and spleen produce blood and this blood was heated or cooled by the heart; Aristotle defended the function of heart as the center in which consciousness, intelligence, and five senses were controlled; Erasistratus put forward a new theory suggesting that the task of the heart is pumping; Galen hypothesized the presence of invisible pores between ventricles and so on (see Appendix G). Students were first asked to read this historical short story, all derived from scientific articles, about scientific views toward the structure and the function of the heart throughout history. During this reading period, students studied changes and developments in scientists' and societies' understanding of the function and structure of the heart chronologically. After they finished reading, students were engaged in some probing questions to make them realize the dynamic nature of the issue and be prepared for following whole-class discussion. Some questions in the handout were as follows: "After reading the above information, how sure do you think that scientists were about the structure of the heart? Please defend your answer" "Do you think that scientists' knowledge on the heart is unchanging? Please explain your answer". After students finished their individual work, the researcher opened the whole-class discussion by first summarizing the disputes among scientists' ideas and letting randomly selected students to share their responses to probing questions. The researcher acted as a guide during the whole class discussion and let the students explicitly and reflectively discuss about the historical material. Based on historical story, students developed ideas and defended their ideas. For example, one student argued that the function of the heart changed from past to present. He defended his claim by referring to the information in the story. Another student proposed a counter claim to this answer and stated that the function of the heart was always the same but different people identified it differently. She justified her ideas as “because people studied on it continuously and refuted the previous ideas by conducting studies”. At this point, researcher asked “Is scientific knowledge always refuted?” Another student responded as “Not always, if new studies are partly consistent with the previous ones, the inconsistent parts may be removed or new parts may be added.” Next the researcher guided students to generalize their thoughts to specific NOS aspect under investigation which was *tentative* nature of science. For example students were asked, “Do you think that this change in the scientists’ ideas can be generalized to other topics in science” “Do you believe that all scientists think in the same way on the same topic?” After being sure that students were focused on the related NOS aspect, tentative nature of science has been discussed with students. It should be noted that this story was the first history of science material in which students expressed personal ideas, developed claims and put forth counterclaims. Informal conversation with classroom teacher and students showed that students had not been involved in such instruction before; so they were not used to it. Because of that, students’ participation was not satisfactory in this activity; therefore researcher posed many guiding question in order to maximize students’ participation to classroom discussion. As participants involved in more HOS activities, they took part in whole class discussions more. As a result during the final activities students were able to involve classroom discussions with little guiding questions of the researcher.

Activity 1 (In Experimental and Comparison Group): This activity intended to investigate the structure and the function of the heart. An important reminder here is that only main parts of these common activities have been outlined here. In order to get deeper and detailed explanations for common activities, it is advisable readers to examine 6th grade teacher handbook (MoNE, 2011). Before activity, students filled the KWL chart and wrote down what they know about heart and its structure and what they want to learn about this topic. After KWL chart, the key concept in human circulatory system has been written on board (heart, blood, vein, artery, capillary, lymph circulation, blood donation) and students were asked what they know about these concepts. The aim for asking about these concepts was to engage them in the topic therefore they were not given any details about them. Next, an analogy between highway intersections and blood vessels has been generated so that students realized that the function of blood vessel in human body resembles to highways. Then the basic components of circulatory system were introduced as heart, blood, and blood vessels. In order to increase students' attention to topic some questions asked to the students including: "Why does blood circulate in the body? Does every individual have the same blood type? Is it necessary to have the same blood type in order to make blood transfusion from one person to other? What are the properties of blood? Does blood have any constituents?" After listening to some students' responses, the focus has been shifted to the core activity. In this activity groups of five students were formed. An activity sheet was given to each group initially (see Appendix H). Each group had a dissection pan and a sheep heart. At the beginning every students were required to wear latex gloves to protect them from potential infectious microbes. Students first observed the outer structure of the heart. And then they draw their observation to the activity sheet and took some notes (shape, color, size, blood vessels and other observation). Next students were shown how to dissect the heart on a sample. Then one of the group members in each group, who were chosen intentionally to be capable of using scissors skillfully and cautiously, split the heart into two starting from aorta. They observed the inner part of the heart (chambers, size of blood vessels and connection of blood vessels with chambers, the muscular walls of ventricles and atria and some other observations). When students were engaging in this activity it was assured that each students observed the blood vessel on the outer structure of the heart; and the thicker muscular structure of ventricles than atria. During this activity further explanation was given to students about following subject:

- The location of heart in human body
- The size of human heart
- The chambers of the heart
- The function of heart valves
- How heart function
- The function of ventricles and atria

Toward the end of the activity students were explained that sheep heart is similar to human heart but other living things, which are not classified as mammalians, has different heart structure (i.e. the number of chamber). In the last part of this activity students were oriented to focus their attention to two science process skills which are *observation* and *inference.* For this aim whole class discussion took place about what they observed about the structure of ventricles and atrium when they investigated the heart and what they can infer from these observations. The discussion started with the teacher's statement "you observed that ventricles had a more muscular wall than atrium" and then the following driving question was asked to engage students in discussion about observation and inference: What may be the reason for this? How can you explain the more muscular structure of ventricles compared to the atrium based on what you learned from activity and classroom discussions? Different answers were received from students. One of them stated that ventricles are below atrium so they are more muscular. Another student inferred that the function of the ventricles is to pump blood to the whole body so they need to be stronger to pump the blood to all body cells and therefore they have a more muscular structure than atrium. Students could infer the function of ventricles as pumping blood to the whole body from their observations about the muscular structure of ventricles. This discussion was based on the fact that students could observe the structure of ventricles but they could not observe the function of it, they only infer based on their observation.

Another discussion on observation and inference was related to the function of blood vessels. They already learned that blood vessels carry oxygen and food to the cells. Students also observed that there are blood vessels on the outer structure of the heart. Based on this knowledge and their observations students inferred that these blood vessels also carry nutrition and oxygen to the cells and tissues of the heart.

Up to this point both groups conducted the same activity and engaged in the same science process skills which were making observation and drawing inference. Beyond this point the experimental group was directed their attention to related NOS aspect which was the distinction between *observation* and *inference.* Through this classroom discussion it was aimed to stress that it is not possible to observe all the topics within the interest of science, therefore it is essential to derive plausible inferences based on observations. Scientists cannot always find direct evidence (observation) studying nature. They may rely on indirect evidence (inference) to explain the nature. To direct students' attention to this point, experimental group students were asked some probing questions to assist them in recognizing the distinction between observation and inference. For example they were asked that "Can we think that scientists directly observed the functions of ventricles?" The typical answer to this question was "we cannot". Their main reason was that they also could not observe it but they inferred from its structure. Then the following question was asked to generalize their understanding for observation and inference to the scientific endeavor: Do you think that scientists only make observations or they also draw inferences in their studies? This question started discussion among students and they concluded that scientists make observations as much as possible but they may draw inferences when they cannot observe. When the discussion about observation and inference was satisfactory, the discussion about subjective nature of science was held.

Students were asked whether our prior knowledge on a topic affects our interpretation of any data?" and the discussion were led to *subjective nature of science*. In this discussion, how scientists' prior knowledge, background information, beliefs and presently held theories influence how they conduct studies, collect data and present results. Students were reminded that they also used their prior knowledge in drawing inferences about the function of the vessels in the outer structure of the heart. They were told that this influenced their inferences about the function of them. They were asked whether scientists also reflect their background in their studies. Students commented on this question and mostly explained that scientists also rely on their background. Next students were asked whether scientists can interpret the same data in different ways. The typical answer to this question was "yes" and then they were required to explain why they think so. One of the students related it to the previous question and emphasized that scientists' background has a role in their interpretations of data. Another student referred to the early ideas of some scientists' about the shape of the earth and added that even though they live on the same planet, some scientists claimed that it was flat while others argued that it was round. After getting students' responses, the differences among individuals' prior knowledge and its relation to subjective nature of scientific knowledge were emphasized. It was noted that scientists are also human beings and they have beliefs, feelings, and ideas and all of these can have impact on their interpretations of data. Some historical information supporting the subjective nature of science was also provided to students. For example bleeding a patient was a common medical treatment in 1800s throughout the world because people believed that demons caused people become sick and some demons was living in the blood. “These could be expelled only be bleeding the patient” (Winner, 2007). This also exemplified how beliefs and presently hold theories affect scientific endeavor.

After Activity 1 was completed in both groups, the experimental group was introduced to the second historical material. At this time comparison group reviewed and solved questions about a topic different than circulation.

Historical short story 2 (Only in Experimental Group): This HOS material was adapted from Hajdu (2003). By the help of this activity students were introduced that knowledge about the constituents of blood had taken a different direction with the invention of the microscopes which enabled to obtain more reliable information and led to the accumulation of knowledge in the field. The nature of science aspect emphasized in this story was that science seeks for empirical evidence derived from observations of the natural world. The difference between science and other disciplines was stated as science relies on empirical evidence. However, at the end of this activity, students were referred to the first activity and it was highlighted that even though science relies on empirical evidence, scientists’ beliefs, background, interests and inferences based on observations influence the science. Through this activity students were also expected to see how different scientists draw different conclusions by looking at the same data or observing the same thing.

Students were initially distributed historical reading material which was about the history of blood cells' discovery (see Appendix I). In this paper students were introduced some key turning points chronologically in the history of discovering blood cells. For example: In ancient times, just because of its color, scientist considered that blood consisted only of small, red drops; in 1658 the German naturalist Jan Swammerdam observed red blood cells under the microscope for the first time; in1695 Antonie van Leeuwenhoek, German microscope expert, identified the size and shape of the red blood cells and drew the first illustration of it (original drawing also provided to students); next 150 years other scientists saw just nothing but red blood cells under the microscope until 1843 when Gabrial Andral, a French professor of medicine, and William Addison, a British practitioner physician, were observed white blood cells independently of each other and other related information was presented. When students finished reading this material, they worked on probing questions related to it. At this point, researcher initiated the whole class discussion about *empirical* and *subjective* nature of science based on the probing questions. Regarding empirical aspect, two main questions were asked: "Which information about the structure of blood seems more scientific; before or after the invention of microscope? And how did the scientific knowledge on blood cells develop through history? These questions were asked to emphasize the importance of empirical evidence in development of scientific knowledge. Some students agreed on that scientists could observe the blood cells with the help of microscope and they obtained more accurate information about the blood cells. Some students referred that microscope helped scientists observe very small cells and they were able to explain them but in the past they could not obtain any observations and could not explain them. The discussion on this aspect was completed by highlighting that science seeks for empirical evidence and this distinguishes science from other disciplines.

Next students were directed to the question "What made scientists couldn't observe all the blood cells at one point in time?" to stress the subjective nature of science. Students were encouraged to share their ideas. Some of them pointed out to the technology as a reason for not being able to observe blood cells at once. It was further explained that although all scientists look at blood under the microscope as William Addison, they could not refer to the white blood cells like him. This was generalized to the epistemology of scientific endeavor highlighting that science is subjective. As a final comment, it was stated that scientists try to explain natural world better based on empirical evidence and their background knowledge may lead to differences in their explanations.

When experimental group completed the discussion about historical material, the second content-specific activity was carried out in experimental and comparison group.

Activity 2 (In Experimental and Comparison Group): This was another common activity in which both experimental and comparison group engaged in. The aim of this activity was to show students that blood consists of plasma and cells. During this activity three science process skills, observing, communicating and inferring, were aimed to develop. First, students made observation using microscope. Then they communicated by explaining their observation and drawing to their classmates. Finally they drew inferences about the existence of blood plasma without directly observing it under the microscope. This activity took place in science laboratory. Students used microscope in this activity therefore they were reminded about how to use it. There were five working microscopes in the laboratory and they were set before the class. The laboratory also included the prepared slide sets for human blood. These slides were placed under each microscope and made ready for observation. Students were required to make fine adjustment for a better focus on the details of the specimen. During the activity students worked individually in each microscope. Due to the lack of enough microscopes four to five students shared a microscope for their observations. This helped the instructors to use the time efficiently. At the beginning of the activity, students were provided a handout to draw their observations (see Appendix J). They only observed red blood cells (erythrocyte) and white blood cells (leukocyte) under the microscopes. After students finished their drawing some probing questions were posed to them. For example: “How many different kinds of cells did you see under the microscope? Do you think that there may be other cells than what you observed in the blood?” Students explained their observations. They discussed about shape, color and the amount of blood cells in the slide. Some students disagreed on shape of the blood cells and observed them again. Finally, a consensus was reached about red blood cells similar to backgammon checkers in red color, regular shape and higher amount compared to the white blood cells. The white blood cells were described as in irregular shape, white color and less in number compared to red blood cells. After receiving students' responses, students were explained that they only observed red and white blood cells. Students were told that in addition to these two cellular structures, there is also another cellular structure called "platelets" in the blood which is too small to be seen via light microscopes used in school laboratory. After blood cells, the discussion was shifted to the "plasma" of blood. The following questions were asked to guide the discussion on it: "Do you think that blood only consists of cells?" Students agreed that the blood only consists of cells. Then they were challenged with the question "If it only includes cells then how it is fluid?" The discussion about it occurred. The flow of blood in the vessels was discussed and students came up with the conclusion that blood should also have liquid component. Next, another question was directed as "Considering that the blood is fluid, what may cause blood to be liquid?" The common answer was that "The blood includes water". The liquid part of blood was introduced as "plasma" which includes 90-92 % water and the rest includes protein, fat, carbohydrates, vitamin, mineral, oxygen, and carbon dioxide. In this activity, students observed the blood cells under the microscope and they inferred that the blood should have another component which makes it fluid based on the fact that it flows in the vessels.

In the last part of this activity, both groups were introduced the basic components of blood with power point presentation. In this presentation students were given detailed information about red blood cells, white blood cells, blood platelets, and blood plasma.

After Activity 2 was completed in both groups, the experimental group was engaged in the third historical material. While experimental group students were receiving this historical material, comparison group reviewed “force and motion” unit.

Historical short story 3 (Only in Experimental Group): This HSS was adapted from Altintas (n.d.); Ozkaynak (2006); Ribatti (2009); Schultz (2002); Shank (1985); and Westfall (1977). Compared to others, this HSS was more comprehensive and focused on more than one aspect of NOS. Through this activity it was intended to make students aware of some common fallacies in scientific enterprise which are: there is a single scientific method that all scientists follow; scientific knowledge is objective, and scientific knowledge does not change. There was also reference to creative and imaginative nature of science, and empirical nature of science.

At the outset of the activity handouts were distributed to students (see Appendix K). In this handout the historical information about human circulatory systems was introduced to students. More specifically, there was information about the fundamentals of Galen’s theory on the physiology of circulatory system; how

Galen's theory remained unchanged over sixteen century even though it was almost completely wrong; how Harvey discovered blood circulation; which methods he had used on the way of discovering circulation; and the basics of Harvey's circulation theory. After students read the historical material on their own, they were required to write their answers for the questions in the handout. These were the questions that guided the upcoming whole classroom discussion. Some of them were "Can we say that Harvey followed so-called "scientific methods" in discovering blood circulation? Why Galen's theory did remained unchanged nearly 1600 years? Why did scientific community determine that Harvey's circulation theory supersede Galen's theory?" After students finished their individual work, researcher initiated the whole class discussion by listening to some students' reflections on probing questions. In the first part of this discussion aforementioned *single-method fallacy* in science was negotiated with reference to Harvey's work (see Appendix K for details of Harvey's work). At the beginning of this discussion most of the students seemed to believe the existence of single scientific method. However, when students were provided with Harvey's work in which he did not follow any step by step procedure, they seemed to be convinced that there is no single scientific method. For example one of the students stated that "I read about Mendel who studied outside with pees, and made observation in most part of his study. He did not follow any stepwise method throughout his study". The discussion on this aspect of NOS was generalized into scientific endeavor by highlighting that there is no single, stepwise scientific method in science.

Next discussion was related to the *subjective* nature of science. In the handout it was underscored that Galen's theory gained acceptance for about1600 years. Even though it was almost entirely erroneous, Galen's theory of human circulation had gone on unchanged for a long time and scientists of those times studied the circulation based on it because it was explaining this complex physiology of circulatory system. As a frame of reference to their whole class discussion, students used the idea that ancient scientists who were inspired by Galenic views reflected a similar pattern on their work about human circulation system. Students discussed that what scientists believe may shape how they study and what they found. In this discussion, one of student's statements was worth noting. She exemplified the subjective nature of science as "some of the ancient scientist believed that earth was the center of the universe therefore they observed that stars and planets orbit the earth every day". The discussion was concluded with the generalization which is the presently-held theories as well as personal characteristics influences the way scientists conduct studies and how they interpret the data and all other processes in science. In other words, it was emphasized that science is not objective.

When the subjective nature of science was stressed through the influence of Galen's theory on other scientists' studies for long years, the discussion was directed toward *tentative* and *empirical* nature of science by emphasizing how Harvey's theory replaced the Galen's. Harvey did not believe in Galen's theory therefore he conducted empirical studies to support his theory. For example Galen proposed that there were pores on the wall between the right and left ventricles which allows the blood pass from right ventricle to left ventricle. On the other hand Harvey denied the existence of these pores by dissecting some mammalian hearts and conducting perfusion experiment (see Appendix K for the details of this experiment). In other words empirical based nature of science was highlighted in this part by the help of Harvey's study. Moreover it was discussed that Harvey provided new empirical evidence on circulatory system that Galen's theory could not explain the complex structure of the circulatory system anymore. Hence new empirical evidence resulted in the change of scientific knowledge on circulation. That is the *tentative* nature of science was underlined. After ensuring that the discussion focused on tentative and empirical based nature of science students were directed to comment on *creative and imaginative* NOS by highlighting the fact that "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" (Lederman et al., 2002, p. 500), so did Harvey in his seminal work. For example, he thought performing perfusion experiment and used mathematical data to justify that blood was not consumed in the body. He made the first attempt to use quantitative data in the history of physiology. It was stressed that majority of his works in his study required creativity and imagination.

After experimental group completed the whole class discussion about third historical material, both group engaged in the next content-specific activity. It was mainly about pulmonary and systemic circulation.

Activity 3 (In Experimental and Comparison Group): This activity was about pulmonary and systemic circulation and consisted of two parts. In the first part, students were supposed to develop simple models of pulmonary circulation and systemic circulation. In the second part, students were engaged in a class game about pulmonary circulation and systemic circulation.

Blood circulation model activities were inspired from Damli and Sivaci (n.d.). At the beginning students formed groups of five-student and each group was provided with required materials (cardboard, play dough, transparent hose, blue and red dyes) and a handout (see Appendix L for handout). In this handout, following information was given to students:

- On the left side of the heart there is always oxygenated (oxygen-rich) blood; and on the right side of the heart there is always deoxygenated (oxygen-poor) blood.
- In the heart, ventricles always pump blood away from the heart; atria always receive blood returning to the heart.
- The arteries always carry blood away from the heart.
- The veins always carry blood toward the heart.

Next, following information was written on the board: "In pulmonary circulation deoxygenated blood (oxygen-poor) is carried away from the heart to the lungs, and oxygenated (oxygen-rich) blood is returned back to the heart." Then groups were asked to create a pulmonary circulation model using the given information and materials. During this activity students were required to color transparent hose to red if they think that it carries oxygenated blood; or to blue if they think that it carries deoxygenated blood so that their model is better understood by other groups. This had a potential to develop misconception among students like “blue blood and red blood”. In order to avoid possibility of developing such a misconception students were told that there is nothing like “oxygenated blood is red while deoxygenated blood is blue”. They were further explained that the aim of coloring the hose into red and blue is just to characterize the types of vessels (arteries or veins) better in their model. After the groups finished their work, they were also told to draw their group model to the handout. After each group worked on pulmonary circulation, students were asked to model systemic circulation. For this purpose following information was written on the board: “In systemic circulation oxygenated blood is carried away from the heart to the body organs, and deoxygenated blood is returned back to the heart.” After students were given this information related to systemic circulation, they were asked to create a model of systemic circulation by following the same steps in pulmonary circulation. After groups finished modeling systemic circulation and drawing their models to the handouts, each group communicated their models to the class. They explained where they placed ventricles, atria, and vessels on the model and discussed about them. When the groups presented their models they submitted their models to the instructor. Then the teacher in comparison group and the researcher in experimental group made a power point presentation to students. In this presentation the types and the functions of blood vessels (arteries, veins, and capillaries) were introduced to students first. Then detailed information about both pulmonary and systemic circulation was presented to students. To consolidate what they have learned so far, students were engaged in the second activity about pulmonary and systemic circulation as mentioned before. In this curriculum adapted activity, a simple representation of pulmonary and systemic circulation were drawn on the floor of laboratory. In this drawing, heart (with its four chambers), lung, and some organs (brain, liver, intestine, and kidney) were included. In this activity students were expected to participate into two tours; short tour (referring to pulmonary circulation), and long tour (referring to systemic circulation). Each student was required to participate both of the tours. The aim of this activity was to visualize the path of blood in pulmonary and systemic circulation through a small class game. In the short tour students were acted as a blood drop and followed the following path:

Right ventricle → *Pulmonary artery* → *Lung* → *Pulmonary vein* → *Left atrium*

In the long tour students were again acted as a small blood drop and followed the following path:

Left ventricle → *Aorta* → *Body organs* → *Upper/lower vena cava* → *Right atrium*

When each student finished the game, they were asked about the path in both circulations. After listening to students, they summarized the main parts of the topic. Up to this point both group experienced the same activity to the extent possible. Ahead of this point, only with experimental group, explicit and reflective classroom discussion took place about targeted aspects which were *empirical, subjective,* and *creative and imaginative* nature of science. First, their models for pulmonary and systemic circulation were given back to groups and their drawings were attached to the board. Then, students were asked some probing question such as "If you have chance to make your models again, do you make modifications on them?" "If you make your model again, will it be more difficult or easier for you to do it?" After students came up with ideas such as "We know more so it will be easier now," "We have more information at hand now therefore we can make more sophisticated models," the discussion were directed to the importance of evidence in science. It was stressed that seeking empirical evidence in nature makes science unique. After ensuring that the whole class discussion focused on empirical aspect of NOS, students were asked "Why each group did not create the same model even though each group was provided the same information about blood circulation?" "Do scientists develop similar models to explain the nature? If so, do they incorporate their insight into the model?" This discussion was focused on the *creative and imaginative* aspect of NOS as well as *subjective* nature of science. During this discussion some of the remarkable discourse was as follows; "we create different model because we imagine differently", "some group's members may have more experience with circulatory system so they may create better model", "the interpretation of given information was different in different groups". Some students further added that "scientists also develop simple models to explain the scientific events", "scientists try to use models to make abstract things more concrete". They were able to discuss that scientists use their imagination and creativity during the process of science. One of the students, for example, stated that “I believe that DNA model is not the same as the real DNA in our body, scientists have created to visualize them using their imagination”. The discussion was ended by emphasizing that “Models are developed when a scientist’s creativity and insight are combined with data and observations about many similar scenarios (“A Closer Look,” 2011).

When the third activity was completed in both groups, experimental group engaged in the next historical material while comparison group reviewed and solved problems about “electricity” unit.

Blood Transfusion Timeline (Only in Experimental Group): In this activity students were required to create a timeline about the historical development of blood transfusion. The information about it was obtained from Atamer (2009); History of Blood Transfusion (n.d.); Maluf (1954); and Uluhan (2011). With the help of this activity students were aimed to demonstrate the development and change in scientific knowledge from XIV century to the present; the key role of observation and experimentation in science; the role of imagination and creativity in the development of science; and the effect of subjectivity in interpreting the same observation.

The researcher identified the key events in the history of blood transfusion. Then a label for each key event was prepared. Each label consisted of images and a brief explanation printed on A4 paper. At the beginning of this activity four groups were formed. They were asked to organize the labels to figure out the development of blood transfusion throughout time. Each group prepared their own timeline using labels provided and used the wall of school science laboratory as the background of their timeline. Some of the interesting historical information in the timeline was as follows: “In XV and XVI century, the blood of young people was believed to avoid agedness and weakness when transfused to old people. With this belief the blood of three 10-year old boys were transfused to Pope by physicians in 1492. Unfortunately, all four died.” “In 1665 a British physician, Richard Lower, succeeded the first recorded blood transfusion. He transfused the blood of dogs to one of injured dog and kept the dog alive.” “Jean-Baptiste Denis in 1667 accomplished the first recorded blood transfusion to a human. He transfused the sheep blood to a man and he survived.” “In 1818 British obstetrician James Blundell was documented as the first person who performed a successful transfusion from one person to another. He transfused blood to a women having postpartum hemorrhage (post-natal bleeding) from her husband” (see Appendix M for the complete labels used in this activity). After each group finished their timeline, a handout (see Appendix M) was distributed to each group in order to let them organize their group views for following whole class discussion. Some of the probing questions in the handout were “Did you find any evidence in your timeline showing that scientific knowledge had been modified or changed?” “Did different scientists in the history of science draw different conclusions from the same data? If so, why did they draw different conclusions?” “Did any scientist integrate his/her own personal opinion into his study?” After groups completed their handout, they first presented their timeline to the class. Next the researcher initiated the whole class discussion. In this part four aspects, *tentative, empirical, creative, and subjective* NOS were discussed. The question “Did you find any evidence in your timeline showing that scientific knowledge had been modified or changed?” was used to guide the classroom discussion to emphasize the tentative NOS. The typical answer to it was that there was evidence showing the change in scientific knowledge. For example one of the students stated that “scientific knowledge about blood transfusion changed during history referring to fact that to meet the need for blood physicians and scientists first transfused blood, and then milk was transfused instead of blood due to unsatisfactory results. However adverse reactions to milk were observed frequently and saline (a special mixture of water and salt) was replaced by milk to meet the need for blood”. Similar answers were received and researcher emphasized that although being durable and reliable scientific knowledge can change in light of new evidence or reinterpretations of evidence; which means that scientific knowledge is never absolute. Following this discussion, the question “what made scientists and physicians change their ideas from blood to milk and milk to saline infusion, and they returned back to blood transfusion again to meet the need for blood?”. Some students explained that “the earlier blood transfusion was not satisfactory and many people died”; “Maybe contaminated blood was transfused”; “scientists could not detect the microbes in the blood in ancient times”. Another student answered as “they observed that some patients had allergic reactions to the milk and they decided to replace it with saline”. Researcher further asked “What do these answers refer to? Do you have any comments?” One student told that “Science is dynamic and open to changes.” Students were challenged with the following question: “What makes science dynamic and open to change?” The common answer was “more evidence and new studies”. Researcher concluded that “Any scientific explanation must be consistent with empirical evidence, and new evidence brings the revision of scientific knowledge” (“Tenets of Nature of Science,” 2011).

The discussion was shifted to the creative NOS by asking students “you learned that some physicians tried to transfuse goat or cow milk to the human. How did scientists come up with these ideas? What do you think? Some answers were “they used trial and error”, “they used their imagination”, and “they might think milk as blood building food”. After receiving similar answers, students were posed the question: “Do scientists use their creativity and imagination in their studies?” Students agreed that scientists use their creativity and imagination. The researcher summed up the discussion and noted that “imagination and creativity are needed in every aspect of a scientist’s work – making sense of observations, making the creative leap from data to possible explanation, coming up with new ideas, designing investigations and looking at old data in a new light”(“Tenets of Nature of Science,” 2011).

The last aspect of NOS emphasized in this discussion was subjectivity. The questions “Did different scientists in the history of science draw different conclusions from the same data? If so, why did they draw different conclusions? Did any scientist integrate his/her own personal opinion into his study?” were directed to the students to initiate discussion. Some example answers were "Yes they did", "The problem was to meet the need for blood and was the same for all scientists but different solutions were suggested by physicians and scientists and I think this was because of the difference in their background", and "The scientist [Karl Landsteiner] discovered the first three blood groups and then his background enabled him to explore Rh factor too". Researcher also highlighted that the scientists are also human beings and they have values, beliefs, prior knowledge, experience, and biases which influence the way they conduct studies and they interpret data. This, results in the fact that science is not objective rather it is subjective.

When the experimental group studied on the history of blood transfusion and the related NOS aspects, the fourth content-specific activity took place in both experimental and comparison group.

Activity 4 (In experimental and Comparison Group): This activity, being common to both groups, was basically about main human blood types. Students were also intended to learn that each blood cannot make blood transfusion with each other through this activity. In terms of science process skills, students were expected to develop the skills of collecting data; graphing; interpreting the graph; and communicating.

For the aim of this activity, students were assigned homework in previous class. It was about learning and taking notes of the blood types of their family member (as many person as possible) including themselves, and bring them to the next class. At the beginning of the activity, all students' and their family members' blood types were tabulated to the board. Next, it was formed groups of five students and they were given graph papers. All groups were expected to create two bar graphs showing the frequency of each types of blood; one for whole class, and one for group members they were in. After all groups finished creating bar graphs, they presented them to the class. Before starting to their presentation they were given the following piece of information: "The most common blood types in Turkey are A, 0, B and AB respectively." In their presentation they talked about the number of people they identified in each blood group; which groups had highest frequency in their group and in the class; and they also compared their findings with the frequency of each blood type in Turkey. When each group finished presenting their graphs, the topics of interest were delivered to comparison group by the teacher and to experimental group by the researcher through power point presentation. In this presentation following topics were covered.

- Four major types of human blood (A, B, AB, 0)
- The essence of blood transfusion
- The importance of Rh in blood transfusion

After they were given detailed information about these topics, the activity was completed by letting students to make decision about who can make blood transfusion to whom in the class.

When the forth common activity was completed in both groups, experimental group engaged in the next historical material while comparison group reviewed and solved problems about “cell” unit.

William Harvey's Experiments (Only in Experimental Group): The aim of this activity was to create an environment in which experimental group students explicitly and reflectively discuss *empirical*, and *creative* and *imaginative* nature of science. This historical course material was a video format material which was produced by Wellcome Film (1971) and sponsored by Royal College of Physicians. It has been stated that this version of the film revised some minor errors in earlier two versions (1928 and 1957) by taking information directly from the Harvey’s original writing and by incorporating new historical research into the film (Wellcome Film, 1971). About the film the company stated that:

> With the aid of animated diagrams and dissections, the film describes the way in which Harvey formulated his revolutionary new theories of cardiac action and of the motion of the blood throgh [sic] the heart, arteries and veins. The commentary is taken very largely from Harvey's own writings, and the film shows how Harvey verified his conclusions regarding the circulation of the blood by repeating his key experiments (Wellcome Film, 1971).

The film was stated as one of the best production ever generated on the history of medicine by Welch Institute of the History of Medicine (Wellcome Film, 1978). In the class the abbreviated version of the film was used. This version consists of five segments. In the first segment there is a brief biography of William Harvey. In this segment there is also a short information on the basics of Galen’s work on the circulatory system which uncontested over sixteen century. The second segment starts with Fabricius's (one of Harvey's colleagues in University of Padua) original drawing which displays the presence of valves in the veins. Toward the end of this part Harvey's observation that heart pumps blood with two motions: "one of the auricles [atria] and the other of the ventricles and they are not altogether simultaneous, but the motion of the auricles [atria] goes before and the motion of the ventricles follows" (Wellcome Film, 1978).This part concludes with showing the heart beats of some animals such as dog, rabbit, and snake. In the third part, the narrator gives information about Harvey's experiments. In this part there is vivisection video showing how heart pumps blood out of the cut on one of eel's aorta. There is an illustration about Harvey's perfusion experiment which enabled to disprove the existence of pores between left and right ventricles. Toward the end of this part Harvey's hypothesis has been emphasized that blood circulates throughout the whole body. In the fourth segment of the video, it is shown some other experiment Harvey conducted to support his hypothesis. For example, in one of the experiment blood flow in a vein of a living snake below the heart has been stopped, and then it is observed that heart becomes smaller and peeler as the blood inside the heart is pumped out. It was given as evidence to show that veins returns blood to the heart back. This part also includes similar experiments as to confirm the direction of blood in the arteries. It ends with demonstrating the difference between arteries and veins by cutting the veins and arteries of a living rat. In the last segment Harvey's experiments about the verification of the existence of valves in the veins were reconstructed. In one of the experiment a thin rod is driven inside the vein from one direction however it stops at a certain point because the valve blocks the way. When the same thin rod inserted from the other direction it can pass all the way through the same vein. In another experiment the arm of a lean man's is tied and in some part of the vein some swellings emerge. It shows the position of the valves in the vein. In the end the narrator explains Harvey's theory of blood circulation.

The language of the video was English and participants did not have a good command of English to understand the video. Therefore, the researcher explained what is mentioned in the video simultaneously. After the experimental group students engaged in this historical material, they were given a handout (see Appendix N) which included some probing questions to make them prepared for coming whole class discussion. Some of the questions in the handout were as follows: "How did Harvey develop a new theory of circulation?" "Did Harvey observe all the process in circulation?" After students completed their individual task, the researcher initiated whole class discussion after listening to some of the opinions of students to the probing questions. In the first part of whole class discussion the focus was on the empirical aspect of NOS. Students explicitly and reflectively discussed the empirical aspect of NOS by taking into account of Harvey's investigations during the development of his theory of blood circulation. Students came to conclude that "instead of blindly accepting what he was told, Harvey dared to question the accuracy and reliability of that knowledge by conducting ample studies". Next they were directed to generalize Harvey's work to the complex epistemology of science. This discussion was completed by highlighting that "science is different because it is supported by logical explanations or concrete evidence" (Hanuscin at al., 2005). After being sure that students' discussion focused on empirical NOS, they were directed to discuss the creative and imaginative aspect of NOS. In this part of whole class discussion experimental group participants stressed that while depicting about circulatory system Harvey did not observe all the things directly. He used his creativity most of the time in generating his theory. For example they stated that "It is his creativity to bring to mind that rod may be used to verify the existence of valves in veins" Also in this part some students referred to the inferential nature of scientific enterprise. After ensuring that the whole class discussion focused on creative and imaginative nature of scientific knowledge the activity has been concluded.

After experimental group students completed this activity by explicit and reflective discussing related NOS aspects, both groups were engaged in the last content-specific activity.

Activity 5 (In Experimental and Comparison Groups): This was the fifth shared activity in which both experimental and comparison group was engaged in. It was about blood donation. By means of this activity students were expected to develop a common sense to blood donation. It was also expected that after finishing this activity students would raise awareness to benefits of blood donation to hospitals, donors, patients and also society.

This activity was conducted at the school's science laboratory. At the beginning of the activity students were divided into four groups. Next each group was assigned a topic. In this activity students were expected to develop a creative drama and exhibit them to the class. One of the following topics was given to each group: "Benefits of blood donation for recipients" "Benefits of blood donation for donors" "The feelings of recipients and their relatives" "The benefits of blood donation to hospitals and the society". As the first step students within each group discussed their ideas on how to dramatize their topic of interest. After students finished planning their creative drama, they dramatized their story to whole class. First group focused on the benefits of blood donation for recipients and emphasized that they get better again after an illness or injury. They also underlined that receiving blood helps people to save their life when they were injured or had surgery. Second group put emphasis on health screening. They stated that before donating blood physicians or nurses conduct a blood test for infectious diseases in donor's blood. They also stressed that experts check their blood pressure before donating blood and this helps to screen their health as well as early diagnosis of some diseases from time to time. Lastly they explained that blood donors get personal satisfaction for saving one's life. The third group generally mentioned about the happiness of recipients and their relatives. They clarified that when someone needs blood in an emergency case; both the person and their relatives become concerned about him/her. When the blood needs are met, everybody feels great and pleased. The last group discussed that blood donation makes the thing easier for hospitals. They explained that having blood banks facilitates emergency medical response to injured people because it is not always possible to find some blood types easily. They concluded that in order to create healthier society volunteer donation is required because donating blood can save the life of a baby, a child, or a young person. When the students completed acting their stories, they shared their experiences to the whole class. In this part, they reflected on the things they learned and felt during the process of preparation and acting. Last, the whole class shared their thoughts to presentation. When the whole class finished their dramatization, the teacher in comparison group and the researcher in experimental group talked about the benefits of blood donation. They also emphasized the fact that Turkey is quite behind of developed countries in terms of voluntary blood donation and there are not enough voluntary blood donors in Turkey. They were also mentioned about the operations of Turkish Red Crescent.

After finishing the activities about blood circulation, the attention was moved to the lymphatic circulation. First of all the definition and function of the lymph were mentioned. Then through the power point presentation the location of lymphatic vessels and lymph nodes on human body was shown on a picture. Tonsils were given as an example of lymph nodes. Then the basic function of lymphatic circulation was explained to students. Toward the end of the implementation students were discussed the importance of circulatory system health. In this part students were talked about the importance of healthy and balanced diet on circulatory system health. They were also explained the hazards of smoking, alcohol, drug, air pollution, stress and fatigue on circulatory system health. They were warned about not to consume too much fast-food; not to eat too much fried dishes. They were encouraged to make sufficient and balanced diet; and to do exercise for the healthier circulatory system. The implementations were concluded by addressing the importance of technologies in the development of novel treatment of circulatory system diseases such as stent, angioma, bypass, and pacemaker.

After the treatment, SPST, CSCT, TOSRA, and VNOS-E were administered to participants in both groups as posttest in order to measure their science process skills, attitudes toward science, understanding of circulatory system concepts, and nature of science views respectively.

Following five weeks students followed national science and technology curriculum as described in teacher guide book. They followed regular activities in their course book. Neither experimental group nor comparison group engaged in historical materials during this time period. At the end of this five week interval they were again administered SPST, CSCT, TOSRA, and VNOS-E to evaluate their follow-up results.

3.6 Ethics

For studies including human subjects, ethical review is imperative in the whole process. This study was conducted with 6^{th} grade students. This age group is known as more vulnerable therefore ethical issues were considered carefully before, during and after data collection process. In this study, firstly, essential documents (purpose of the study, consent form, parent consent form, instruments, and activities) were reviewed by ethical committee in Middle East Technical University and there were no concerns related to the ethics. The second ethical review was performed by the ethical committee in Ministry of National Education. The committee investigated the study in terms of ethical issues such as confidentiality, the content of activities, and age level appropriateness. The study was also approved by the second ethical committee and the school was informed about it. Before data collection process, the researcher communicated with school administration and the teacher. The teacher was selected long time ago voluntarily since this would be more effective especially in implementing the study. The students were informed about the study very briefly and they were told that the data collected would be accessed only by the researcher. They were also informed that the concept test administered for the study would not affect their scores on Science and Technology course. Researcher stated that the involvement in the study was based on voluntary participation and students have right not to complete instruments and not to participate activities at any time during the study. They were even told that they were free to withdraw any time from the study if they chose not to continue. Signed parent consent forms were collected before data collection from each student who participated in the study. The parents were informed about the study and the contact information of the researcher was provided. They were encouraged to feel free to contact and ask question to the researcher at any time about the study. As the last ethical consideration there was no concern about physical and psychological harm to participants and no deception in the nature of the study.

3.7 Data Analysis

In this study both qualitative and quantitative data sources were utilized. First of all, a one-way MANOVA was conducted to inspect whether there was any preexisting difference between the groups on the collections of SPST, CSCT, and TOSRA. Next, Repeated-measures MANOVA was used to test whether two instructions had created different profile in terms of science process skills, understanding of science concepts, and attitudes toward science. After finding statistically significant difference between the profiles of two groups through repeated-measures MANOVA, follow-up analyses were run for each DV separately to gain a deeper understanding about them. For this purpose three separate mixed between-within subjects of ANOVAs were conducted on students' science process skills, understanding of circulatory system concepts, and attitudes toward science scores respectively. Next, in order to inspect between-group difference, two separate independent-samples t-tests were conducted: one for posttest and one for follow-up test. In order to compensate inflated type I error causing from multiple testing, alpha rate was set as .025 for each test to account for 2 comparisons (0.05/2). Hence, results were evaluated based on 97.5 % confidence interval. Also in order to see within-group difference two separate one-way repeated measures ANOVAs were conducted: one for experimental group, one for comparison group. When the difference between time periods was found to be significant in the analysis, three separate comparisons among time pairs for each group were utilized across three time periods: one for pretest to posttest, one for posttest to follow-up test, and one for pretest to follow-up test. Accordingly, 6 potential comparisons might lead to increased type I error rate. So as to compensate inflated type I error possibility originated from multiple comparisons, alpha rate was situated at .008 (0.05/6) owing to 99.2 % confidence interval through within-group comparisons.

In the second part of the data analysis, participants NOS views were explored in detail. This part was divided into two parts. In the first part, students NOS views were compared between two groups while in the second part within group comparison took place for each group separately. The main data about NOS understanding of students were collected through VNOS-E as stated earlier.

In order to evaluate and score participants' responses to VNOS-E, a rubric was developed. Before developing the rubric, the studies using different forms of VNOS instruments were reviewed. This guided the categories and their descriptions for the rubric used in this study. Moreover, twenty completed VNOS-E instruments were selected randomly and open coding was performed for emerging themes and patterns to develop categories and their descriptions. In addition to VNOS-E, researcher's field notes (including individual, small group, and whole class discussions), KWL charts, informal conversations with the teacher and students, students’ handouts, and activity sheets were used to enhance trustworthiness of the categories and their descriptions in the rubric. The researcher studied with a NOS expert during the analysis of VNOS-E. This expert had a strong background in NOS studies. After developing the rubric, researcher and the expert analyzed a subset of responded VNOS-E instruments independently to reveal that the rubric measures what it is supposed to measure. In the first step of analysis the researcher and the expert were independently analyzed five sets of randomly selected participants' VNOS-E responses. In this comparison, the significance of the inter-rater reliability was tested using Cohen's Kappa. The results of the inter-rater analysis were Kappa = .78 with $p < .001$. It means that there were significant agreements between the researcher and the expert. Also Landis & Koch (1977) stated that Kappa values from 0.40 to 0.59 are considered moderate, 0.60 to 0.79 substantial, and 0.80 outstanding. For a convincing agreement, Kappa values should be at least 0.6 and most often higher than 0.7. According to this result it was safe to assume that there was a substantial agreement between the researcher and the expert in the first set of evaluation. To further establish validity and reliability of the rubric, a second five sub-set of randomly selected papers was analyzed. The significance of the inter-rater reliability was tested using Cohen's Kappa again. The results of the inter-rater analysis was Kappa = .89 with $p < .001$. The second analysis also supported significant agreement between them. After each of these two sessions two coders come together and discussed coding for each participant and discrepancies in interpretations were resolved and reached an agreement. Table 3.10 presents the rubric for VNOS-E which developed and validated by the researcher and NOS expert for 6th grade students.

Table 3.10 Developed Rubric for VNOS-E during the Study: Categories and Their Descriptions

Aspect	Naïve	Transitional	Informed
Empirical	Fail to differentiate science from other school subjects. Views science as totally belief-based. May consider scientists to talk through their heads.	Recognize the value of empirical evidence in science but at the same time equates science to other school subjects.	Underline that science seeks for evidence or data. Recognize the role of science as investigating natural events. May emphasize that scientists observe nature/phenomena to find evidence and approach situations using evidence
Tentative	Ascribe science to reveal unknown facts. Believe that science discover the reality. Views science as the accumulation of proven data. May equate science to inventions.	Recognize the development of science but hesitate to characterize it as change. Consider scientific knowledge as subject to change but may express that sometimes science may prove things. Degrade scientific change to technological development.	Recognize that what scientists know is subject to change. Describe science as an attempt to find new interpretations. Consider science as dynamic and evolving.
Subjective	View science as universal, society-independent and bias-free. Views subjectivity as a significant threat to validity of science.	Attribute science as bias and opinion free enterprise but at the same time identify scientists as self-reflecting in conducting science.	Identify scientists as of all people and recognize that they may have different world views. May stress inevitable role of scientists' background in interpreting data.
Creative and Imaginative	View creativity and imagination as a threat to the trustworthiness of science. Describe science as a systematic attempt and routine process.	Recognize that scientists use their imagination and creativity only in the early phase of their studies. May underline that science partially include creativity and imagination.	Be aware that scientists use creativity and imagination in the whole scientific process. Recognize science as mental process in which scientists design what they imagine. May highlight creativity as the emerging point of scientific knowledge.

Table 3.10 (Continued)

Inferential	View direct evidence as the sole source of scientific knowledge and do not give credence to indirect evidence. Believes that scientists should see or observe the things to be confident about it.	Recognize the presence of indirect evidence in science but still view direct observation or seeing as the convincing evidence.	Recognize that it is not always possible to find direct evidence therefore scientists need to make logical predictions. Underline that scientists task include to consider every possibility and make sound predictions.

In this rubric students' views were categorized into three level as "naïve" "transitional" and "informed". During the analysis NOS profiles of students were analyzed based on their collectivist responses to the instrument instead of limiting analysis to one-to-one correspondence between a question on the instrument and a specific aspect of NOS. According to Khishfe and Abd-El-Khalick (2002); and Lederman et al., (2002) this approach has two important advantages. First it allows researcher to analyze participants NOS views in multiple contexts. Second this approach allows researchers to evaluate participants NOS understanding meaningfully instead of evaluating of key term replications. In order to show how participants' NOS profiles established, an example was provided in Table 3.11.

Table 3.11 An Example NOS Profile of a Student in the Study

Aspect	Collection of the Answer	Profile
Empirical:	This student referred that science requires evidence. S/he also referred that accumulation of empirical evidences leads to develop scientific knowledge. S/he stressed that different tools can be used to study the nature empirically. S/he believed that scientists seek for evidence to explain any phenomena.	Informed
Tentativeness	This student explicitly referred that science can change. S/he also stressed that what scientist found may be incorrect from time to time. S/he referred dynamic nature of scientific knowledge as well. On the other hand, s/he believed that it is sometimes possible to reach ultimate reality or accurate knowledge. This student thinks scientific ideas change because we were 'wrong' in the past; but also recognizes that this may come from different perspectives.	Transitional
Subjective	S/he mentioned the personal interpretations of evidence. S/he accepted that scientist can look the situations based on their own judgments. S/he also stresses the personal position (proponent or opponent) of scientists toward theories.	Informed
Creative	This student stressed that creativity plays role in trying alternative ways to evaluate evidence. S/he also accepted that different phases of science include imagination and creativity which help scientists in varied ways. S/he accepts that creativity facilitates scientists' work	Informed
Inferential	S/he referred that scientists study on evidences and based on those they infer about what is unknown. S/he had an idea that all phenomena cannot be observed directly. S/he also stressed inference is worth in science.	Informed

In order to avoid possible bias of data collection and analysis, the analysis of students' responses to VNOS-E was postponed until the end of follow-up administration as suggested by Abd-El-Khalick, Bell, and Lederman (1998). At the beginning of analysis, all VNOS-E papers, which were used during the course of the study, were mixed together. Then one was randomly selected among them and without looking at its groups (experimental or comparison) and sequence of administrations (pretest, posttest, or follow-up test) it was assessed. In the analysis five aspects of NOS was handled one by one. Each student's NOS understanding were evaluated by giving 1 point to “naïve” views; 2 point to “transitional” views; and 3 point to “informed views on each aspect separately. Then VNOS-E scores of experimental and comparison groups at pretest, posttest, and at follow-up test were compared separately for each aspect. To test the statistical significance between groups Contingency Table Analyses (Pearson Chi-square Test and its extensions) was utilized. To test the NOS views of students within each group, McNemar's Test was utilized by providing some of the representative quotes to each aspect. Also analyses were elaborated with descriptive data.

3.8 Validity

Internal Validity. Internal validity means that the differences found in the outcome variable occur as a result of the independent variable in the study (Fraenkel & Wallen, 2006). Subject characteristics, mortality, location, instrumentation, testing, history, maturation, regression, and implementation are the internal validity threats that can emerge in a study (Fraenkel & Wallen, 2006). Subject characteristics, location, testing, and maturation were potential threats to internal validity in this study. However, subject characteristics threat was determined to be inoperative after finding a non-significant group difference on pretest scores of participants on collective DVs. Namely two groups did not differed significantly from each other in terms of science process skills, understanding of circulatory system concepts, science process skills and nature of science views. Location was not assumed to cause any problem because the study was conducted in the same school. In other words experimental and comparison classes were at the same school. Testing might cause some problems to internal validity due to the repeated design nature of the study. But it was accepted that these threats affected both groups in the parallel way because they have completed the tests at similar times. Maturation also is not a serious threat since there is limited time for the intervention and data were collected from both groups in similar time frames. Lastly implementation might be a potential threat since the teacher delivered instruction to comparison group while the researcher delivered instruction to experimental group. In order to minimize implementation threat to internal validity common content-specific activities were outlined before the class by the collaboration of classroom teacher and the researcher based on teacher handbook. Additionally the researcher and the teacher observed each other during the implementation. Therefore both group engaged in similar content-specific activities to the extent possible.

CHAPTER IV

RESULTS

In this study the effectiveness of history of science instruction over curriculum-oriented instruction in terms of Grade six students' science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science NOS views were compared by means of pre, post and follow up measurements.

4.1 Analysis of Participants' Science Process Skills, Understanding of Science Concepts, and Attitudes toward Science

Under this heading, students' science process skills, understanding of circulatory system concepts, and attitudes toward science were investigated quantitatively. Accordingly, Repeated-Measures MANOVA was utilized to examine the data related to these variables. Since the participants' prior science process skills, prior understanding of science concepts, and prior attitudes toward science may affect their post-treatment or follow-up test scores, which in turn might threat the validity of the inferences, one-way MANOVA was run prior to Repeated-Measures MANOVA on participants' pretest scores and it was presented first. Then, the description of doubly multivariate design and justification for how the nature of the study is compatible with this design were presented. Next, required assumptions checks were reported in detail for the appropriateness of the data for Repeated-Measures MANOVA and corresponding test results were provided. Guided by Tabachnick and Fidell's (2012) suggestions, results were reported on each dependent variable separately due to deviation from parallelism between groups (statistically significant interaction). Whenever other assumptions were required for follow-up analysis, the results of assumption checking were reported just before the tests.

4.1.1 Analyses of Participants' Pretest Scores

One-way MANOVA was conducted to compare the groups with respect to the pretest scores on the combination of abovementioned dependent variables. In the following sections, evaluation of underlying assumptions, descriptive statistics, and result of the test were presented respectively.

4.1.1.1 Evaluation of Assumptions of One-way MANOVA

There are numerous assumptions of One-way MANOVA namely minimum required sample size for each cell, univariate normal distribution of the cases, absence of univariate outliers, multivariate normal distribution, absence of multivariate outliers, straight-line relationship between each pair of dependent variables, absence of multicollinearity and singularity, and homogeneity of variance-covariance matrices. These were discussed in the following sections in detail.

4.1.1.1.1 Sample Size

When conducting MANOVA, it is essential to have more cases than dependent variables in each cell (Tabachnick & Fidell, 2012). In this study, there were 51 participants in experimental group and 44 participants in comparison group. In both groups there were only one individual who had missing scores at pretest. There were also three dependent variables in the study. Therefore there were many more participants than required in each cell.

4.1.1.1.2 Univariate Normality

The skewness and kurtosis statistics for pretest scores of Science Process Skills Test (SPST), Circulatory System Concepts Test (CSCT), and Test of Science-Related Attitudes (TOSRA) of both groups were presented at Table 4.1. The table illustrated that the values lay between -.99 and .61. These values were within the range of tolerable values. Therefore there was no concern about univariate normality.

Table 4.12 Skewness and Kurtosis Values of Each Test Prior to Treatments

	Experimental Group		Comparison Group	
	Skewness	Kurtosis	Skewness	Kurtosis
SPST	.38	-.80	.47	-.23
CSCT	.17	-.95	-.22	-.59
TOSRA	-.36	-.34	-.99	.61

4.1.1.1.3 Absence of Univariate Outliers

Tabachnick and Fidell (2012) explained that the univariate outlier is any case in the data that has a large standardized score. They also mentioned that cases having $z >$

+3.29 or $z < -3.29$ ($p = .001$) are possible outliers. Table 4.2 shows the range of standardized score for each dependent variable at pretest.

Table 4.13 Highest and Lowest Standardized Scores of Each Test Prior to Treatments

	Standardized Score (*Z* Score)	
	Highest	Lowest
SPST	2.51	-1.64
CSCT	2.10	-2.30
TOSRA	1.75	-2.61

As shown in the table, there was not any case having standard scores greater than $|3.29|$ in the data. Therefore, it was concluded that there was not any univariate outlier in the data at pretest scores.

4.1.1.1.4 Multivariate Normality

Tabachnick and Fidell (2012) discussed that MANOVA is robust to even modest violation of the multivariate normality when there are 20 or more degrees of freedom for error. In this case there were 89 degrees of freedom for error ($N = 93$, $DVs = 3$). Also Mardia (1971) clarified that MANOVA is robust to the violation of multivariate normality when there are around 20 sample size for each cell with a few dependent variables, even with unequal sample size between groups. In this study there were 43 cases in the smallest cell and there were 3 dependent variables. Hence it was safe to conclude that even violation of multivariate normality for pretest scores is not expected to pose a threat to the validity of interpretations of the results.

4.1.1.1.5 Absence of Multivariate Outliers

In order to check whether the data have multivariate outliers, SPSS Regression process was run to create Mahalanobis distance. In order to check whether the data have multivariate outliers, the criteria of the critical value of Mahalanobis distance was used at $p < .001$. As suggested by Tabachnick and Fidell (2012), Mahalanobis distance was assessed using chi-square (χ^2) table and the degrees of freedom (df) value was taken as the number of DVs, in this case it was three. Therefore, depending on Chi Square Table, any case having Mahalanobis distance larger than χ^2 = 16.27 (Tabachnick & Fidell, 2012, p. 952) is treated as multivariate outlier. The cases were sorted in descending order in terms of Mahalanobis distance. The first five values were given at Table 4.3.

Table 4.14 Highest Mahalanobis Distances of DVs Prior to Treatments

No	Group	Case Number	Statistic
1	2	88	8.49
2	2	86	8.45
3	2	73	8.17
4	2	54	7.74
5	1	39	6.79

As seen in Table 4.3 there was not any Mahalanobis distance which was larger than 16.27. It referred that there was not any multivariate outlier in the data.

4.1.1.1.6 Linearity

Linearity assumption was evaluated separately using matrix scatter-plots for each group in the study (Figure 4.1).

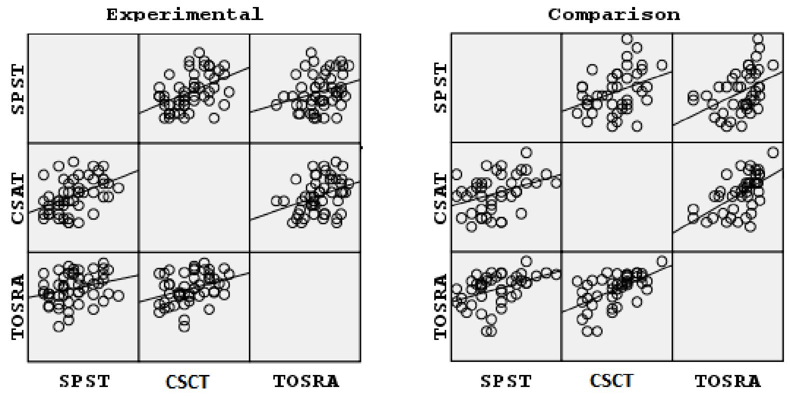

Figure 4.1 Matrix Scatterplots of Pretests Scores of SPST, CSCT, and TOSRA for Groups

The two matrix scatterplots above illustrates that there is no noticeable evidence indicating non-linearity.

4.1.1.1.7 Absence of Multicollinearity and Singularity

In order to check multicollinearity, SPSS Correlation was run to see the degrees of correlation among dependent variables at pretest. The result was tabulated at Table 4.4.

Table 4.15 Correlation Coefficient among Tests Prior to Treatments

	SPST	CSCT	TOSRA
SPST	1.00		
CSCT	.41	1.00	
TOSRA	.36	.46	1.00

As seen in Table 4.4 all the correlation between variables were moderate according to Cohen (1988)'s guidelines. This illustrated that there was not multicollinearity among variables at pretest. Singularity happens when one of the variables becomes the combination or sub-dimension of other variable/s. The instruments used across this study measures totally different constructs, so there was no concern about singularity too.

4.1.1.1.8 Homogeneity of Variance-Covariance Matrices

This assumption was tested using Box's M test. The result of the Box's Test of Equality of Covariance Matrices was tabulated below (Table 4.5).

Table 4.16 Result of Box's Test for Equality of Covariance Matrices at Pretests

Box's M	F	Significance
4.62	.74	.616

This table provided information about the assumption of homogeneity of variance-covariance matrices. When the table was examined, it was clear that the Box test was not significant at the .05 significance level, F (6, 56386) = .74, p = .616. Accordingly, the data met the assumption of homogeneity of variance-covariance matrices.

4.1.1.2 One-way MANOVA for Pretest Scores of SPST, CSCT, and TOSRA

The research question tested in this part was; “To what extent experimental and comparison group students differ in terms of collective dependent variables of science process skills, understanding of circulatory system concepts, and attitudes toward science prior to the treatments”. Statistical Package for Social Sciences (SPSS) 15 was used and statistical decision was made at p = .05 significance level. Descriptive statistics on the pretest scores of both groups were presented in Table 4.6.

Table 4.17 Mean and Standard Deviation Scores of the Groups Prior to Treatments

	Group	Mean	Std. Deviation	N
SPST	Experimental	13.04	4.08	50
	Comparison	12.88	4.82	43
CSCT	Experimental	14.28	3.93	50
	Comparison	14.70	4.29	43
TOSRA	Experimental	3.45	.51	50
	Comparison	3.40	.55	43

As shown in the table, both groups seemed to have similar mean values on the pretest scores. Experimental group appeared to have slightly better science process skills and a little more favorable attitudes toward science while comparison group was slightly better at understanding circulatory system concepts prior to the treatments.

After meeting the assumption and presenting the descriptive information about the pretest scores of DVs, the result of one-way MANOVA was described to figure out whether two groups differed in terms of pretest scores of collective DVs. Table 4.7 shows one way MANOVA result. Tabachnick and Fidell (2012) stated that Wilks' Lambda is the most common used criterion among others if there is nothing wrong with the assumption forcing researcher to use Pillai's criterion, a more conservative test. All the assumptions were met for one-way MANOVA; therefore Wilks' lambda was reported.

Table 4.18 Multivariate Test Result for Pretest Scores

Source	Wilks' Lambda	F	Significance	Partial Eta Squared
Pretests	.99	.29	.832	.01

Based on the Wilks' Lambda criterion, there was not a statistically significant difference between experimental group and comparison group in terms of combined DVs prior to the treatments, F (3, 89) = .29, p = .832, Wilks' Lambda = .99, partial η^2 = .01. This result implies that there was not a preexisting difference between experimental and comparison group in terms of science process skills, understanding of science concepts on human circulatory system, and attitudes toward science.

4.1.2 Multivariate Analysis of Pretest, Posttest, and Follow-up Test: Doubly Multivariate Design

4.1.2.1 Description of Doubly Multivariate Design

Doubly multivariate design is an extension of profile analysis where at least two different DVs are measured several different times during the study. Tabachnick and Fidell (2012) stated that "Rapidly growing in popularity is the use of repeated-measures MANOVA for the doubly multivariate designs where several DVs, not all measured on the same scale [noncommensurate], are measured repeatedly" (p. 314). In this study, three quantitative DVs of two groups (experimental, and comparison) have been measured three times (prior to treatment, post-treatment, and five-week follow-up) over the course of the study. Therefore, for the purpose of this study, the researcher conducted Repeated-Measures MANOVA as the main statistical analysis. Besides, follow-up tests were performed whenever necessary. SPSS (Statistical Package for the Social Sciences) 15 program was utilized for the analysis of the data.

4.1.2.2 Justification for how the Nature of the Study is Compatible with Doubly Multivariate Design

In this study noncommensurate DV's were measured repeatedly. To be more specific, students in experimental group and comparison group were measured three times during the course of the study on science process skills, understanding of circulatory system concepts, and attitudes toward science. "Both the within-subjects part of the design [Time 1, Time 2, Time 3][1] and the multiple DVs were analyzed multivariately", so the analysis becomes doubly multivariate (Tabachnick & Fidell, 2012, p. 343). To remind, at the very beginning of the each analysis, related assumptions were reported to determine the appropriateness of data and then corresponding analyses results were discussed. Whenever other assumptions required for follow-up analysis, they were checked and presented just before the tests. Moreover, the abbreviations[2] of the instruments were used in most part of result section.

4.1.2.3 Evaluation of Assumptions of Repeated-Measures MANOVA

4.1.2.3.1 Missing Data and Sample Sizes

At the beginning, ninety-five grade 6 students participated to the study. Table 4.8 shows the result of preliminary analysis of missing data.

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[1]Throughout the study the following terms have been used interchangeably: prior to treatment = Time 1; post-treatment = Time 2; five-week follow-up = Time 3.

[2]TOSRA for Test of Science-Related Attitudes; CSCT for Circulatory System Concepts Test; SPST for Science Process Skills Tests

Table 4.19 Missing Data Identification

	Group	Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
Pretest							
SPST	E*	48	94.1 %	3	5.9 %	51	100 %
	C**	42	95.5 %	2	4.5 %	44	100 %
CSCT	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
TOSRA	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
Posttest							
SPST	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
CSCT	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
TOSRA	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
Follow-up							
SPST	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
CSCT	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %
TOSRA	E	48	94.1 %	3	5.9 %	51	100 %
	C	42	95.5 %	2	4.5 %	44	100 %

*E represents experimental group
**C represents comparison group

As seen in Table 4.8, three participants in experimental group and two participants in comparison group had one or more missing scores on at least one of the instruments in the data. Since just five cases had missing score and they were distributed evenly among two groups, researcher had decided to delete them from data. In addition to missing cases, there was one disabled student in one of the comparison classes. Data from this student was also excluded from the analysis because this student was out of the target population of this study. Of the remaining 89 participants, 48 were in experimental group and 41 were in comparison group. According to Tabachnick and Fidell (2012) “there should be more research units in the smallest group than there are DVs" in repeated-measures MANOVA (p. 317). In this study there were 13.7 times more participants than the number of DVs in the smaller group, thus sample size was appropriate for repeated-measures MANOVA.

4.1.2.3.2 Accuracy of Input, and Univariate Normality

Descriptive statistics were utilized to examine accuracy of data entry and distribution of scores. All related values were tabulated at Table 4.9.

Table 4.20 Descriptive Statistics for SPST, CSCT, and TOSRA

	Mean	Std. Dev.	Skewness	Kurtosis	Minimum	Maximum
Pretest						
SPST	12.94	4.35	.48	-.36	5.00	25.00
CSCT	14.49	4.09	.05	-.91	7.00	24.00
TOSRA	3.43	.53	-.69	.16	1.96	4.36
Posttest						
SPST	13.76	5.21	-.07	-.95	4.00	25.00
CSCT	23.72	4.13	-.30	-.54	14.00	30.00
TOSRA	3.65	.55	-.75	.25	2.01	4.50
Follow-up						
SPST	13.79	4.30	.05	-.59	4.00	23.00
CSCT	20.48	4.85	.11	-.83	10.00	30.00
TOSRA	3.68	.46	-.95	.75	2.16	4.38

In the table, the means, standard deviations, minimum, and maximum values were examined to determine whether all the scores are within the acceptable range. For example TOSRA was a 5 point Likert scale and the values of the scores are supposed to change from 1 to 5. When the descriptive statistics regarding, for example, pretest TOSRA checked, it was seen that the mean value is 3.43 with minimum value = 1.96, and maximum value = 4.36. These values were within the range of plausible output as were the values on the other variables. These statistics were checked for other DVs for each of three time period and results showed that there was not any unusual value, which indicates the accuracy of data entry process.

According to Table 4.9, the skewness values of DVs changed within the range of -.95 and .48 and the kurtosis values changed from -.95 to .75. These skewness and kurtosis values were within the acceptable range for all of the DVs. Based on skewness and kurtosis results, there was no concern about the divergence of data from univariate normal distribution. Histograms (see Appendix O) also supported that there was not much deviation from normality.

4.1.2.3.3 Univariate Outliers

According to Tabachnick and Fidell (2012) the univariate outlier is any case in the data that has a large standardized score. They also put forward that cases having $z > +3.29$ or $z < -3.29$ (at $p = .001$) are possible outliers. Table 4.10 shows the range of standardized score for each DV at three time periods.

Table 4.21 Highest and Lowest Standardized Scores for SPST, CSCT, TOSRA

	Standardized Score (*Z* Score)	
	Highest	Lowest
Pretest		
SPST	2.77	-1.83
CSCT	2.32	-1.83
TOSRA	1.76	-2.75
Posttest		
SPST	2.16	-1.87
CSCT	1.52	-2.35
TOSRA	1.54	-2.98
Follow-up		
SPST	2.14	-2.27
CSCT	1.96	-2.16
TOSRA	1.53	-3.32

There was at least one potential univariate outlier in the follow-up test of TOSRA (Table 4.10). When the data file inspected for univariate outlier, it was noticed that case 73 was the one having -3.32 *z*-score from the follow-up test of TOSRA. There was no other case having standard scores greater than |3.32| in the data. The mean score of this case from follow-up test of TOSRA was 2.16. A mean score of 2.16 is within the acceptable range for any case in comparison group; therefore, the researcher decided to retain it for the analysis.

4.1.2.3.4. Multivariate Normality

Repeated-Measures MANOVA, a special type of profile analysis, is robust to violation of normality unless there are smaller numbers of cases than DVs in the smallest group and the groups have substantially unequal sample sizes (Tabachnick & Fidell, 2012). In this study groups were large enough and the case ratio of experimental group to control group is just 1.17, therefore there was no concern for the violation of the assumption of multivariate normality.

4.1.2.3.5 Multivariate Outlier

Tabachnick and Fidell (2012) stressed that Repeated-Measures MANOVA is extremely sensitive to outliers. Therefore, possible multivariate outliers were analyzed and results were discussed in detail. First, in order to find possible multivariate outliers in the sample, SPSS Regression process was run to create Mahalanobis distance. This measure has been defined as “the distance of a case from the centroid of the remaining cases” by Tabachnick and Fidell (2007, p. 386). To check whether the data have multivariate outliers, the criteria of the critical value of Mahalanobis distance at $p < .001$ was used. As suggested by Tabachnick and Fidell (2012), Mahalanobis distance was assessed using chi-square (χ^2) table and the degrees of freedom (df) value was taken as the number of DVs, in this case it was three. Therefore, depending on Chi Square Table, any case having Mahalanobis distance larger than $\chi^2 = 16.27$ (Tabachnick & Fidell, 2012, p. 952) was treated as multivariate outlier. The cases were sorted descending in terms of Mahalanobis distance. The first ten values were provided at Table 4.11.

Table 4.22 Highest Mahalanobis Distances for Collective DVs

No	Group	Case No.	Statistics
1	1	24	21.84
2	2	92	15.04
3	1	23	14.58
4	2	73	14.10
5	1	39	13.34
6	2	95	13.19
7	1	29	12.88
8	1	44	12.85
9	2	56	12.84
10	2	54	12.70

As shown in the table, case 24 had Mahalanobis Distance = 21.84 exceeding the critical chi-square value of $\chi^2 = 16.27$. According to Tabachnick and Fidell (2012) it is essential to look for why any case is an outlier. Therefore SPSS Regression was used to see why this case diverges from other cases.

Before conducting stepwise regression, dummy variable were created to separate case 24 from other cases. The key point here was that case 24 was belong to experimental group so dummy coding created just for experimental group and comparison group excluded from the analysis for this part. Regression analysis results were reported to show which variables distinguish case 24 from other cases in experimental group (Table 4.12). In this step, dummy variable was used as DV and actual DVs were used as IVs to see the divergence of outlier from other cases.

Table 4.23 Dependent Variables Making the Case 24 an Outlier

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	Constant	.54	.18		3.02	.004
	TOSRA (Time 3)	-.14	.05	-.40	-2.92	.005
2	Constant	.65	.17		3.71	.001
	TOSRA (Time 3)	-.41	.12	-1.19	-3.45	.001
	TOSRA (Time 2)	.25	.10	.86	2.48	.017

As seen in the Table 4.12, posttest and follow-up test scores of the TOSRA were two significant predictors of why the case 24 deviated multivariately from other cases. This means that the mean TOSRA scores of case 24 at posttest and follow-up test was considerably different than the means scores of other participants in experimental group.

The last step of analyzing the reason of being multivariate outlier was to find out how case 24 differ from other cases on these two variables. SPSS Descriptive procedure was run to examine these two variables as depicted in Table 4.13.

Table 4.24 Descriptive Statistics of Case 24 and Other Cases in Experimental Group

dummy		N	Mean
0*	TOSRA (Time 2)	47	3.80
	TOSRA (Time 3)	47	3.80
1**	TOSRA (Time 2)	1	2.93
	TOSRA (Time 3)	1	2.65

*0 represent cases in experimental group except case 24
**1 represents case 24 in experimental group which is found to be multivariate outlier

Table 4.13 shows that the 24th case had considerable lower score on both posttest and follow-up test score of TOSRA than other cases in experimental group. Because of potential harm to the accuracy of inference from the data, case 24 was deleted from analysis leaving 88 cases for the analysis. After deletion of the multivariate outlier, there were 47 subjects in experimental group and 41 subjects in comparison group for the analyses.

4.1.2.3.6 Linearity

This assumption refers to straight-line relationship between each pair of DVs. This assumption was evaluated separately using matrix scatter-plots for each group in the study. Considering matrix scatterplots (see Appendix P), it can be inferred that there was not any fundamental evidence supporting non-linearity. Besides Tabachnick and Fidell (2012) confirmed that the assumption of linearity may be ignored with many normally distributed sample and large sample size. In the study normality assumption was met and the sample size was large enough. Accordingly there was nothing to worry about the assumption of linearity.

4.1.2.3.7 Absence of Multicollinearity and Singularity

Multicollinearity and singularity happen when the pairs of variables correlate highly. Tabachnick and Fidell (2012) underlined that multicollinearity and singularity cause two problems; logical problem and statistical problem. They pointed out that if the bivariate correlations among the variables are .70 or more, logical problem takes place, and they advised to eliminate one of the bivariate correlating variables in the analysis. They maintained that statistical problems, caused by singularity and multicollinearity, arise when the correlation among two variables are .90 or higher (pp. 89-90). Tabachnick and Fidell (2012) clarified that "Correlations among DVs are expected to be quite high when they are the same measure taken from the same cases over time [i.e. for repeated measures]. Therefore, only statistical multicollinearity poses difficulties, and even then only if tolerance is less than .001 for the measures combined over groups." (p. 319). Keeping this in mind, .90 or higher bivariate correlation among variables and tolerance is less than .001 were used as a criteria to test multicollinearity due to the repeated measure of variables in the study. Table 4.14 demonstrates the correlation among the DVs.

Table 4.25 Correlation Coefficient among SPST, CSCT, and TOSRA

	Pretest			Posttest			Follow-up		
	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA
Pretest									
SPST	1.00								
CSCT	.45	1.00							
TOSRA	.36	.50	1.00						
Posttest									
SPST	.68	.53	.40	1.00					
CSCT	.49	.57	.35	.43	1.00				
TOSRA	.22	.44	.61	.33	.38	1.00			
Follow-up									
SPST	.60	.46	.35	.84	.41	.33	1.00		
CSCT	.38	.40	.23	.38	.70	.34	.41	1.00	
TOSRA	.22	.44	.58	.30	.41	.92	.27	.33	1.00

According to the Table 4.14, the only correlation threatening the data is between posttest TOSRA and follow-up TOSRA with r = .92. This was not an unexpected happening because the same instrument was used at both post and follow-up measurements on the same subjects across the study. Therefore, it was considered as an expected result. Tolerance was also checked for the presence of multicollinearity. In fact, tolerance is defines as 1-SMC (Squared Multiple Correlation) where SMC serves as DV and remaining DVs serve as IVs in multiple correlation. Whenever SMC is high, it means that the variable has a high correlation with the set of other variables in the data and the data have multicollinearity (Tabachnick & Fidell, 2012). Table 4.15 below shows the tolerance statistics of DVs.

Table 4.26 Tolerance Value for Assessing Multicollinearity

	Pretest			Posttest			Follow-up		
	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA
Tolerance	.47	.52	.53	.24	.37	.13	.28	.47	.14

Although bivariate coefficient between posttest TOSRA and Follow-up TOSRA score were suspected multicollinearity, there was not any tolerance value less than .001accompanying bivariate r for multicollinearity. Therefore, it was safe to conclude that there was not enough evidence to support multicollinearity among variables.

Singularity happens when one of the variables becomes the combination or sub-dimension of other variable/s in the analysis. The instruments used across this study measures totally different constructs, so there was no concern about singularity in this sense. Besides, Tabachnick and Fidell (2012) expressed that “If the SMC is 1, the variable is perfectly related to others in the set and you have singularity (p. 90)”. Taking into consideration the equation that “Tolerance = 1-SMC”, and if SMC = 1 then to be singular, tolerance must be equal to 0. Checking Table 4.15 showed that all tolerance values were substantially greater than zero. In consequence, it was also safe to posit that there was no threat for singularity. These two results indicated that the data have met the assumption of both absence of multicollinearity and singularity.

4.1.2.3.8 Homogeneity of Variance and Homogeneity of Variance-Covariance Matrices

Homogeneity of variance-covariance matrices assumes that the variance-covariance of the DVs for groups is sampled from similar population variance-covariance matrices, so allows pooling them to create a single estimate of error (Tabachnick & Fidell, 2012). According to Tabachnick and Fidell (2012), evaluation of this assumption is not necessary if the sample sizes are equal. Stevens (2007) suggested that when the ratio of largest group size to smallest group size is less than 1.5, multivariate test is robust to violation of this assumption. In this study this ratio is about 1.15 (47/41). Univariate homogeneity of variance also required to be met and advised that unless sample sizes are extremely deviating from each other, this assumption safely ignored (Tabachnick & Fidell, 2012). These posit suggest that there was not a big threat for the related assumptions but for the sake of the analysis the researcher checked it statistically.

Table 4.27 Levene Test for Homogeneity of Variance

	Pretest			Posttest			Follow-up		
	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA
Stat.	.99	.29	.06	.44	1.67	.76	.95	1.35	1.47
Sig.	.322	.591	.809	.510	.200	.385	.332	.249	.228

Table 4.16 indicates that all the Levene statistics were non-significant at p = .05, therefore it can be concluded that there was no violation of the assumption of homogeneity of variance.

The result of Box's Test of Equality of Covariance Matrices was depicted in Table 4.17 which gives information about the assumption of homogeneity of variance-covariance matrices.

Table 4.28 Box's Test of Equality of Covariance Matrices

Box's M	F	Significance
58.33	1.15	.226

When the table was examined, it is clear that the Box test was not significant at the .05 level (F = 1.15, p = .226). In consequence the data was met the assumption of both homogeneity of variance and homogeneity of variance-covariance matrices.

After completing the necessary screening procedure of the data and assumption check, the result of main analysis, Repeated-Measures MANOVA, was presented.

4.1.2.4 Repeated-Measures MANOVA for Multivariate Analysis of Pretest, Posttest, and Follow-up Test Scores of SPST, CSCT, and TOSRA

After checking the assumptions and meeting them, a Repeated-Measures MANOVA was performed on the data obtained from two groups in the study. The between-subject IV (levels) was types of instruction. The within-subjects IV was the three sessions of testing. The three noncommensurate DVs were attitudes toward science, science concepts understanding, and science process skills.

Repeated-Measures MANOVA is not a frequently used analysis; therefore, the hypotheses it test was described briefly before reporting the results.

4.1.2.4.1 Parallelism Test

This hypothesis tests whether the profiles of groups are parallel or not (Stevens 2009; Tabachnick & Fidell, 2012). With the best known term in univariate tests, it is known as the test of interaction. The following research question was tested by means of parallelism test: “To what extent HOS instruction and curriculum-oriented instruction create different profiles on the collective DVs across three testing conditions?” or in statistical words: “Do experimental and comparison groups have parallel profiles on the collective set of DVs over the three testing condition?”

4.1.2.4.2 Level Test

In Repeated-Measures MANOVA what is known as the test of levels is actually tests the overall difference among groups. In other words, it analyze whether one group score higher on the collective DVs than other group (Tabachnick & Fidell, 2012). It deals with the similar question with between-subject main effect in repeated-measures ANOVA. The research question tested with level hypothesis is as follows: “To what extent does one method lead to the higher score on the collected set of DVs than the other?”

4.1.2.4.3 Flatness Test

Tabachnick and Fidell made clear that the last question addressed by Repeated-Measures MANOVA tests whether all DVs have had similar gain or lost throughout the study independent of groups. In other words it tests; “Do all the DVs elicit the same average response?” In Repeated-Measures MANOVA analysis it is called as “flatness” hypothesis. “This question is typically relevant only if the profiles are parallel” (2012, p. 316). Actually these three hypotheses can be investigated by means of Repeated-Measures MANOVA.

4.1.2.4.4 The interpretation of Parallelism, Level, and Flatness Test

Results of Repeated-Measures MANOVA for levels (Group), flatness (Time), and parallelism (Time*Group) appear in Table 4.18.

Table 4.29 Multivariate Test Result for Repeated-Measures MANOVA

Effect	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Group	.92	2.40	3	84	.074	.08
Time	.12	99.15	6	81	.000	.88
Time*Group	.76	4.17	6	81	.001	.24

The parallelism test produced statistically significant result with respect to combined DVs with p = .001. It means that there was statistically significant differences among two groups in their profiles on the combined DVs. Effect size was found to be medium according to Cohen’s criteria (1988) with partial η^2 = .24.

This result implied that HOS based instruction and curriculum-oriented instruction created different profile regarding three core dimension of scientific literacy with the time; and the magnitude of this nonparallel profile was not small. The profiles of the groups were shown in Figure 4.2.

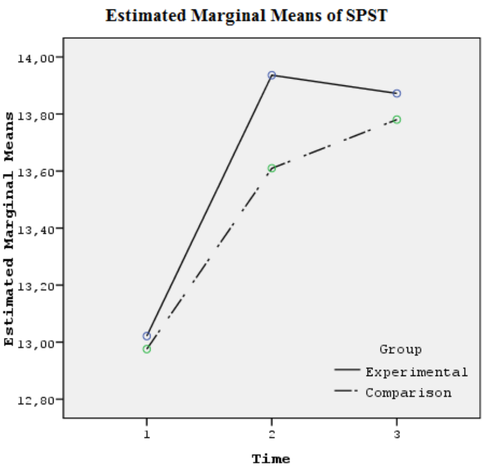

Figure 4.2a The Profiles of the Groups over Time Regarding SPST

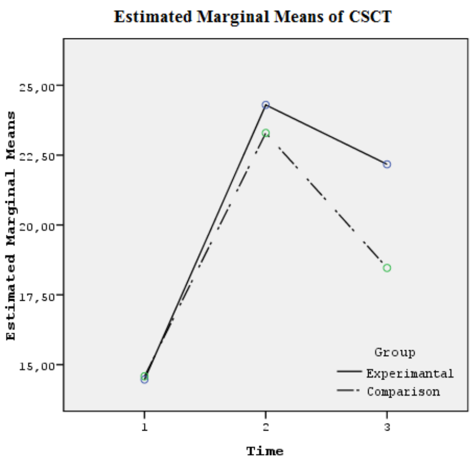

Figure 4.2b The Profiles of the Groups over Time Regarding CSCT

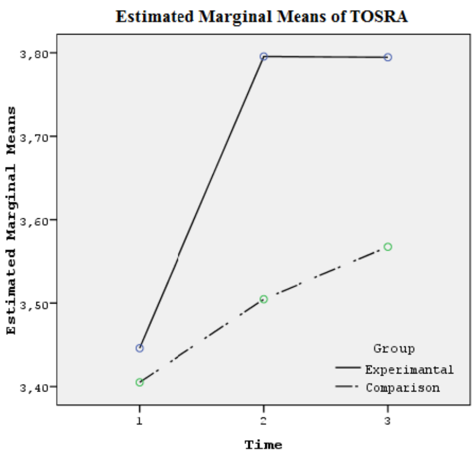

Figure 4.2c The Profiles of the Groups over Time Regarding TOSRA

Although, it is clear that the profiles of experimental and comparison group are different, it is still ambiguous which DV or DVs split the groups. To find out this, follow up tests are needed but before conducting it, flatness and level tests were reported. According to Tabachnick and Fidell (2012) when the parallelism test is rejected, typically testing flatness and level hypothesis are not relevant. But to generate an idea about flatness and level hypotheses with this data, it was decided to report them here.

It is clearly shown in Table 4.18 that the level test is not significant with p = .074, Wilks' Lambda = .92. In addition, with Cohen (1988) criteria it has small effect size (partial η^2 = .08).

On the other hand, flatness test reached statistical significance, multivariate F (6, 81) = 99.15, p < .0005, Wilks' Lambda = .12, partial η^2 = .88. Mean and standard deviation statistics for the plots can be found at Table 4.19.

Table 4.30 Descriptive Statistics of DVs

		Pretest			Posttest			Follow-up		
	Group	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA	SPST	CSCT	TOSRA
Mean	E*	13.02	14.47	3.45	13.94	24.30	3.80	13.87	22.17	3.80
	C**	12.98	14.59	3.41	13.61	23.29	3.51	13.78	18.46	3.57
Std.	E	4.01	3.93	.52	5.34	4.19	.49	4.56	4.72	.39
Dev.	C	4.74	4.34	.56	5.19	3.79	.57	4.05	4.28	.48

*E represents experimental group
**C represents comparison group

The result of Repeated-Measures MANOVA yielded a significant parallelism and flatness test while it yielded a non-significant level test. These results suggested that the change in collective DVs of SPST, CSCT, and TOSRA was not same over three session of testing between experimental and comparison groups; and the change in each DV was not same over the testing. In other words HOS based instruction and curriculum-oriented instruction did not lead to the same change over time. In order to interpret nonparallel profiles of two groups, follow up test was necessary for each dependent variable separately. Tabachnick and Fidell (2012) suggested simple-effects analysis in case of significant parallelism and flatness test, and non-significant level test. They added that the group means should be compared separately for each DV in such cases. In the following part, the comparison of groups was presented for each dependent variable separately. In fact there were multiple comparisons among the groups, so Bonferroni-type adjustment was used whenever necessary while making the statistical decision on results. In the first part SPST; in the second part CSCT; and in the third part TOSRA results were reported.

4.1.3 Follow-up Test Results

4.1.3.1 Follow-up Test Results for SPST

The result of Mixed between-within subjects of ANOVA was presented to show the difference between two treatments on students' science process skills. Underlying assumptions of sample size, normality, homogeneity of variance were checked and the results revealed that all the assumptions were satisfied (see sections 4.1.2.3.1; 4.1.2.3.2; 4.1.2.3.8 respectively for the details). Another assumption was homogeneity of intercorrelations. According to Box M test, this assumption was also met, F (6, 50909) = 8.82, p = 507. One additional assumption for mixed between-within ANOVA is sphericity assumption. It was assessed through Mauchly's Test of Sphericity. In this analysis, sphericity assumption was violated (p = .003); therefore, multivariate test (which does not require sphericity assumption) results for within-subject part was reported. Table 4.20 shows the results of multivariate test for within-subject and interaction effect; and Table 4.21 shows between-group main effect test result for SPST.

Table 4.31 Within-Group Multivariate Test Result of SPST

Effect	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Time	.95	2.13	2	85	.125	.05
Time*Group	1.00	.09	2	85	.912	.00

Table 4.32 Between-Group Main Effect of SPST

Effect	F	df	Error df	Significance (p)	Partial Eta Squared
Group	.03	1	86	.863	.00

Before checking for the main effects, it was suggested to assess the interaction effect which tests whether there is similar change in science process skills of students over time for the groups. For SPST the interaction effect was not significant with a significance value of .912. Equally, the main effect for time (p = .125) and group (p = .863) were not significant. Hence it can be concluded that there was no statistically significant interaction among the teaching methods and time in terms of science process skills, Wilks λ = 1.00, F (2, 85) = .09, p = .912, partial $\eta^2 < .0005$. There was also statistically non-significant main effect for time Wilks λ = .95, F (2, 85) = 2.13, p = .125, partial η^2 = .05. Lastly the main effect for two groups in terms of science process skills was not significant F (1, 86) = .03, p

= .86, partial $\eta^2 < .0005$ implying that there was not enough evidence to conclude that one of the instructions has superiority over the other in terms of improving science process skills. Based on the result, it is also possible to claim that the change in SPST scores over time is similar for HOS based and curriculum-oriented instructions. Table 4.22 shows mean scores of two groups across three time periods in terms of SPST.

Table 4.33 SPST Scores of Two Groups across Time

	Experimental Group			Comparison Group		
	N	M	SD	N	M	SD
SPST (Time 1)	47	13.02	4.01	41	12.98	4.74
SPST (Time 2)	47	13.94	5.34	41	13.61	5.19
SPST (Time 3)	47	13.87	4.56	41	13.78	4.05

4.1.3.2 Follow-up Test Results for CSCT

The result of Mixed between-within subjects of ANOVA was discussed in this part to illustrate the difference between two treatments on students' understanding and retention of circulatory system concepts. Preliminary analysis of sample size (sections 4.1.2.3.1), normality (sections 4.1.2.3.2), homogeneity of variance (section 4.1.2.3.8) showed that there was no violation of these assumptions. Also Box M test provided that homogeneity of intercorrelations assumption was met too, F (6, 50909) = 1.25, p = 276. On the other hand, Mauchly's Test of Sphericity indicated that sphericity assumption was violated (p = .001). Thus, multivariate test results were reported for within-subject main effect and interaction effect. Table 4.23 and 4.24 illustrates the result of main analyses.

Table 4.34 Within-Group Multivariate Test Result of CSCT

Effect	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Time	.13	284.40	2	85	.000	.87
Time*Group	.82	9.44	2	85	.000	.18

Table 4.35 Between-Group Main Effect of CSCT

Effect	F	df	Error df	Significance (p)	Partial Eta Squared
Group	4.03	1	86	.048	.05

Table 4.23 demonstrates that there was a significant interaction effect between the types of instruction and time ($p < .0005$) in terms of CSCT. It means that there was not the same change in scores of CSCT over three time periods for two groups. Figure 4.2b (see section 4.1.2.4.4) shows the profile plot of CSCT across three time periods. The profile plot in the figure clearly shows that when the students progress through weeks, the gap between mean scores of groups on the science concepts test broadened and the students having HOS based instruction increasingly outperformed over the students having curriculum-oriented instruction as the time passes. To sum up, based on the profile plot, it can be concluded that students in HOS classes retained their science concepts understanding better than students in other classes.

The profile plot gave a clear picture of the change in CSCT scores of both groups. However, it did not give any evidence on the statistical significance of the change. In other words we know that both groups' CSCT scores increased at posttest similarly and a decrease was observed in both groups' follow-up test scores.

However, the decrease was sharper for comparison group. There was a need to test statistical significance of these changes. For this aim, the interaction effect was further analyzed.

4.1.3.2.1 Further Examination of the Interaction Effect for CSCT

In this part of the result, the interaction effect in CSCT scores of two groups was explained further in an attempt to address three research questions of interest:

1. What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to understanding of circulatory system concepts at post-instruction and follow-up measurements?
2. How do experimental group students' understanding of human circulatory system concepts change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?
3. How do comparison group students' understanding of human circulatory system concepts change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?

In order to examine the first research question, two separate independent-samples t-tests were conducted: one for posttest and one for follow-up test. The reason why the posttest was compared was that, the researcher was interested in whether one treatment has superiority over another just after the treatment in terms of understanding of circulatory system concepts. Follow-up score was also compared because the researcher was also interested in whether one group had retained content knowledge better than the other group.

For the second and third research questions, two separate one-way repeated measures ANOVAs were conducted. When the difference between time periods was found to be significant in the analysis, three separate comparisons among time pairs for each group was utilized across three time periods: one for Time 1 to Time 2, one for Time 2 to Time 3, and one for Time 1 to Time 3. The rationales for these multiple comparisons were as follows;

Time 1 to Time 2: This comparison tested whether there was a significant change in students' post-treatment CSCT scores compared to their prior to treatment CSCT scores.

Time 2 to Time 3: This comparison tested whether there was a significant change in CSCT scores of students at follow-up test compared to their scores on posttest.

Time 1 to Time 3: This comparison was conducted to see whether students' understanding of human circulatory system concepts were better at follow-up measurement when compared to their preexisting understanding. What should be noted here is that; time-pair comparisons were held within each group. First the results of the experimental group analysis were given; later the same comparison results were introduced for comparison group.

4.1.3.2.1.1 Between-Group Comparisons for CSCT

Under this subtitle, two groups' CSCT scores on post and follow-up measurements were reported. Consequently there were 2 comparisons in total. In order to compensate for inflated type I error causing from multiple testing, alpha rate was set as .025 for each test to account for 2 comparisons (0.05/2).

For the independent-samples t-tests, homogeneity of variance assumption was checked to see whether variation of scores for two groups was similar. The significance levels for Levene's test were p = .200 and p = .249 for posttest and follow-up test, respectively. These two values are above the cut-off point .05. Therefore, the data did not violate the assumption of homogeneity of variance assumption. As presented in section 4.1.2.3.2, skewness and kurtosis values indicated that there was no violation of normality assumption either post or follow-up measurements.

Table 4.36 Independent-Samples t-Tests Result of Posttest and Follow-up Test of CSCT

					Confidence Interval (97.5 %)	
	t	df	Significance	Mean Difference	Lower	Upper
CSCT (Time 2)	1.17	86	.244	1.01	-.95	2.96
CSCT (Time 3)	3.84	86	.000	3.71	1.51	5.91

In Table 4.25, it is seen that the mean difference between posttest scores of CSCT was not statistically significant for experimental (M = 24.30, SD = 4.19) and comparison (M = 23.29, SD = 3.79) groups; t (86) = 1.17; p = .244. The magnitude of mean difference was small, $\eta^2 = 0.02$. A note here is that, the magnitude of difference (η^2 value) was calculated using Formula 1.

Formula 1. Eta Squared Formula for t-Test

$$\eta^2 = \frac{t^2}{t^2 + df}$$

Substituting the values from Table 4.25:

$$\eta^2 = \frac{1.17^2}{1.17^2 + 86}$$

$$\eta^2 = 0.016$$

According to the guidelines proposed by Cohen (1988), 0.016 is a small effect size. This value expresses that, only nearly 2 percent of the variance on the posttest scores of CSCT could be explained through the types of instruction. This result suggests that there was no considerable difference between mean scores of two groups just after the treatment in terms of understanding of circulatory system concepts.

On the other hand, the mean follow-up test scores of CSCT of experimental group (M = 22.17, SD = 4.72) were significantly higher than comparison group (M = 18.46, SD = 4.28); t (86) = 3.84; $p < .0005$. The magnitude of this mean difference was large, $\eta^2 = .15$. It means that almost 15 percent of the variance on the follow-up test of CSCT could be explained by the types of instruction. This finding implies that the difference found between the experimental and comparison groups at follow-up test arouse from the natures of treatment and this difference has practical value in terms of retaining content knowledge. In other words it is proper to conclude that HOS instruction enabled better retention of science content knowledge than curriculum-oriented instruction.

4.1.3.2.1.2 Within-Group Comparisons for CSCT

This part focuses on the changes in the CSCT scores over three time periods (Time1, Time 2, and Time 3) within each group separately. To check if there was a statistically significant mean difference among three sets of scores in each group, two separate one-way repeated measures ANOVAs were employed after splitting file according to the types of instruction. As can be checked in section 4.1.2.3.2, skewness and kurtosis values indicated that there was no violation of normality assumption across three times of testing. Also Levene test in Table 4.16 indicated that homogeneity of variance assumption was satisfied. Hence, it is safe to interpret the results.

As shown in Table 4.26, one-way repeated measures ANOVA result for experimental group was significant: Wilks' Lambda = .12, F (2, 45) = 159.68, $p <$ .0005, multivariate partial eta squared = .88. This result suggests that there was a significant difference in CSCT scores of experimental group over three time periods of testing.

Likewise the mean CSCT score of students in comparison group was significantly different across time: Wilks' Lambda = .14, F (2, 39) = 124. 65, $p < .0005$, partial eta squared = .87. It indicated that there was a statistically significant change in CSCT scores of comparison group across three times periods too.

Table 4.37 Multivariate Test Results of One-Way Repeated Measures ANOVA for CSCT

Group	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Experimental	.12	159.68	2	45	.000	.88
Comparison	.14	124.65	2	39	.000	.87

Having obtained statistically significant results from one-way repeated measures ANOVA, paired sample t-tests were utilized to check whether there was statistically significant mean difference between pretest to posttest; posttest to follow-up test; and pretest to follow-up test. Experimental group was handled first and comparison group was handled next.

4.1.3.2.1.2.1 Pairwise Comparison of CSCT: Experimental Group

In this part of the result section, the CSCT scores of experimental group were presented to determine which set of scores differ from one another regarding CSCT. Particularly, researcher seeks to find answer to the following questions:

1. How do experimental group students' understanding of human circulatory system concepts change from pre-instruction to post-instruction?
2. How do experimental group students' understanding of human circulatory system concepts change from post-instruction to follow-up measurements?
3. How do experimental group students' understanding of human circulatory system concepts change from pre-instruction to follow-up measurements?

To find answer to these questions, three paired-samples t-test were conducted at .008 alpha levels. Table 4.27 shows paired-samples t-test results of experimental group in terms of CSCT scores.

Table 4.38 Paired-Samples t-Test Results of CSCT Scores of Experimental Group

Pairs	t	df	Sig.	Mean Difference	Confidence Interval (99.2 %)		Eta Squared*
					Lower	Upper	
Time 1-Time 2	-17.84	46	.000	-9.83	-11.36	-8.30	0.87
Time 2-Time 3	5.40	46	.000	2.13	1.04	3.22	0.39
Time 1-Time 3	-12.23	46	.000	-7.70	-9.45	-5.96	0.77

*Eta Squared has been calculated using Formula 1.

Table 4.27 illustrates that there was a statistically significant increase in CSCT scores from pretest (M = 14.47, SD = 3.93) to posttest (M = 24.30, SD = 4.19) for the students in experimental group (for mean and standard deviation statistics, see Table 4.28 below), t (46) = -17.84, p < .0005. The mean increase in CSCT scores is 9.83. According to Cohen (1988), the magnitude of this difference was very large (η^2= .87). This finding implied that HOS instruction improved students' circulatory system concept understanding.

The table 4.27 also illustrates that there was a significant decrease in experimental groups students' CSCT scores from posttest (M = 24.30, SD = 4.19) to follow-up test (M = 22.17, SD = 4.72); t (46) = 5.40, p < .0005. The actual mean difference between groups was 2.13. Eta squared statistics (η^2= .39) shows that this decrease was large. In the context of the current research, this finding implies that five week after the treatment students receiving HOS instruction were unable to retain their understanding of circulatory system concepts at the posttest level.

The last point emerged from Table 4.27 was that the experimental group at follow-up test (M = 22.17, SD = 4.72) had significantly higher score than their pretest score (M = 14.47, SD = 3.93); t (46) = 12.23, p < .0005. The mean CSCT score difference was equal to 7.70. The effect size between mean scores was still very large (η^2 = .77). This significant difference between follow-up test and pretest suggested that experimental group students' understanding of circulatory system concepts five week after the treatment was better than that of prior to the treatment. The means and standard deviations for three time periods were presented at Table 4.28 for the groups.

Table 4.39 Descriptive Statistics for CSCT

	Experimental Group (N = 47)		Comparison Group (N = 41)	
	M	SD	M	SD
CSCT (Time 1)	14.47	3.93	14.59	4.34
CSCT (Time 2)	24.30	4.19	23.29	3.79
CSCT (Time 3)	22.17	4.72	18.46	4.28

4.1.3.2.1.2.2 Pairwise Comparison of CSCT: Comparison Group

In this part of the result section, the CSCT scores of comparison group were presented to determine which CSCT scores differ significantly from each other. Particularly, researcher seeks to address the following questions:

1. How do comparison group students' understanding of human circulatory system concepts change from pre-instruction to post-instruction?

2. How do comparison group students' understanding of human circulatory system concepts change from post-instruction to follow-up measurements?
3. How do comparison group students’ understanding of human circulatory system concepts change from pre-instruction to follow-up measurements?

Paired-samples t-tests were utilized to compare pretest-posttest; posttest-follow-up test; and pretest-follow-up test scores of CSCT. The results of these comparisons were tabulated at Table 4.29.

Table 4.40 Paired-Samples t-Test Results of CSCT Scores of Comparison Group

					Confidence Interval (99.2 %)		
Pairs	t	df	Sig.	Mean Difference	Lower	Upper	Eta Squared*
Time 1-Time 2	-14.95	40	.000	-8.71	-10.33	-7.08	0.85
Time 2-Time 3	8.12	40	.000	4.83	3.17	6.49	0.62
Time 1-Time 3	-5.11	40	.000	-3.88	-6.00	-1.76	0.40

*Eta Squared has been calculated using Formula 1.

According to Table 4.29, there was a statistically significant mean increase for comparison group from pretest (M = 14.59, SD = 4.34) to posttest (M = 23.29, SD = 3.79) on CSCT; t (40) = -14.95; $p < .0005$. The average increase from pretest to posttest was equal to 8.71. This average mean increase had a large effect with eta squared = .85. (For mean and standard deviation statistics, see Table 4.28). This result showed that students in comparison group gained reasonably high science content knowledge after the treatment.

The CSCT scores of comparison group from posttest (M = 23.29, SD = 3.79) to follow-up test (M = 18.46, SD = 4.28) decreased significantly; t (40) = 8.12; p <

.0005. The average decrease in mean scores was equal to 4.83. Eta squared statistics showed very large effect for this decrease ($\eta^2 = .62$). This finding shows that understanding of circulatory system concepts of students in comparison classes declined reasonably five week after the treatment.

At five-week follow-up test, the mean CSCT scores (*M* = 18.46, *SD* = 4.28) of students in comparison group was significantly higher than that of their pretest scores (*M* = 14.59, *SD* = 4.34); $t\ (40) = -5.11$, $p < .0005$. The average mean scores difference from follow-up test to pretest was equal to 3.88. The difference between follow-up to pretest had large effect size with $\eta^2 = .40$. In other words, comparison classes were better at understanding of circulatory system concepts five weeks after the treatment compared to their initial understanding of circulatory system concepts.

4.1.3.3 Follow-up Test Results for TOSRA

In order to find out the relative effectiveness of two different types of instruction on students' attitudes toward science across three time periods, another mixed between-within subjects of ANOVA was conducted on TOSRA scores of two groups. In this part, multivariate test results were reported for within-subject main effect and interaction effect part of the analysis due to the violation of sphericity assumption ($p < .0005$). The following two tables present the result of mixed between-within subjects ANOVA in terms of TOSRA across time.

Table 4.41 Within-Group Multivariate Test Result of TOSRA

Effect	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Time	.75	14.15	2	85	.000	.25
Time*Group	.93	3.32	2	85	.041	.07

Table 4.42 Between-Group Main Effect of TOSRA

Effect	F	df	Error df	Significance (p)	Partial Eta Squared
Group	3.77	1	86	.056	.04

As it can be inferred from Table 4.30, there was a statistically significant interaction between the types of instruction and time in terms of TOSRA scores; Wilks λ = .93, F (2, 85) = 3.32, p = .041, partial eta squared = .07. It means that the change in attitudes of students' toward science was different over three time periods for experimental and comparison group. Although both groups showed an increase in TOSRA scores just after the treatments compared to their pretest scores, the increase appears to be sharper in experimental group (see Figure 4.2c).

Figure 4.2c also shows that the mean difference between groups becomes less 5 weeks after the completion of the study when compared with the difference in posttest scores. However, compared with their pretest scores, striking difference still exists between experimental and comparison group five weeks after the completion of the study in favor of experimental group students. Table 4.32 shows mean and standard deviation scores of both groups in terms of TOSRA across three time periods.

Table 4.43 Descriptive Statistics for TOSRA

	Experimental Group (N = 47)		Comparison Group (N = 41)	
	M	SD	M	SD
TOSRA (Time 1)	3.45	.52	3.41	.56
TOSRA (Time 2)	3.80	.49	3.51	.57
TOSRA (Time 3)	3.80	.39	3.57	.48

The profile plot and mean scores of both groups provided valuable information about the change in TOSRA scores of both groups. However, it did not give any evidence on the statistical significance of the change. Therefore the following part allocated for the explanation of statistical evaluation of interaction effect on the TOSRA scores of experimental and comparison groups.

4.1.3.3.1 Further Examination of the Interaction Effect for TOSRA

Due to a significant interaction effect between the types of instruction and time, further analyses were needed for both between groups and within group of each instruction through time. As in the previous section, two separate independent-samples t-tests were utilized for the posttest and follow-up test scores of TOSRA to see if there was significant difference between the scores of two groups. Next, two separate one-way repeated measures ANOVAs were conducted to inspect whether there was a significant difference among three time periods for each group separately. Similar to the previous part, alpha was set as .025 to evaluate between group differences; and .008 for within group comparison. The following research question was investigated in this part of the result section:

1. Is there a significant mean difference between the groups exposed to HOS and curriculum-oriented instruction in terms of attitudes toward science on posttest, and on follow-up test?
2. Do the TOSRA scores of experimental group change significantly during three time period?
3. Do the TOSRA scores of comparison group change significantly during three time period?

4.1.3.3.1.1 Between-Group Comparison for TOSRA

This part of the result mainly describes the comparison of the posttest and follow-up test scores of experimental and comparison group in terms of TOSRA. To explore these, independent-samples t-test was used as a statistical tool. Independent-samples t-test requires the assumption of equality of variance. Following table presents the result of Levene's test.

Table 4.44 Levene's Test for Equality of Variance

	F	df	Sig.
TOSRA (Time 2)	.76	86	.385
TOSRA (Time 3)	1.47	86	.228

The Levene results for posttest (*p* = .385) and follow-up test (*p* = .228) of TOSRAs revealed that both data meet the assumption of equality of variance. Also, skewness and kurtosis values, presented in section 4.1.2.3.2, indicated that there was no violation of normality assumption either post or follow-up measurements. The results of independent-samples t-tests were given at Table 4.34.

Table 4.45 Independent-Samples t-Tests Result of Posttest and Follow-up Test of TOSRA

	t	df	Sig.	Mean Difference	Confidence Interval (97.5 %) Lower	Upper	Eta Squared*
TOSRA (Time 2)	2.560	86	.012	.29	.03	.55	.07
TOSRA (Time 3)	2.45	86	.016	.23	.02	.44	.07

*Eta Squared has been calculated using Formula 1.

Table 4.34 reveals that the mean difference between experimental group (*M* = 3.80, *SD* = .49) and comparison group (*M* = 3.51, *SD* = .57) in terms of posttest scores of TOSRA reached statistical significance; t (86) = 2.56; p = .012. The mean difference between two groups was equal to .29. The magnitude of this difference in the means was moderate (eta squared = .07). This finding implied that, nearly 7 percent of the variance on the mean posttest scores of TOSRA can be explained by the types of instruction. This result also shows that students receiving HOS instruction had more favorable attitudes toward science than students receiving curriculum-oriented instruction, just after the treatment.

Similarly, TOSRA scores of the experimental group (*M* = 3.80, *SD* = .39) were significantly higher than comparison group (*M* = 3.57, *SD* = .48) five weeks after the treatment; t (86) = 2.45; p = .016. The magnitude of mean difference (mean difference = .227) was medium, η2 = .07. This means that nearly 6.5 percent of the variance on the follow-up test of TOSRA can be explained by the types of instruction. Overall, this finding revealed that, experimental group students still exhibited more favorable attitudes toward science than comparison group students, even five weeks after the treatment.

4.1.3.3.1.2 Within-Group Comparison of TOSRA

This section focuses on the changes in the TOSRA scores over three time periods (Time1, Time 2, and Time 3) within each group separately. To check if there was a statistically significant mean difference among three sets of scores in each group, two separate one-way repeated measures ANOVAs were employed after splitting file according to the types of instruction.

Table 4.46 Multivariate Test Results of One-Way Repeated Measures ANOVA for TOSRA

Group	Wilks' Lambda	Multivariate F	Hypothesis df	Error df	Significance (p)	Partial Eta Squared
Experimental	.59	15.69	2	45	.000	.41
Comparison	.87	2.81	2	39	.072	.13

As shown in Table 4.35, one-way repeated measures ANOVA result for experimental group was significant; Wilks' Lambda = .59, F (2, 45) = 15.69, $p <$ .0005, partial eta squared = .41. It implies that attitudes of students in experimental groups significantly changed across time. The means and standard deviations statistics for three time periods were presented at Table 4.32.

While TOSRA scores of experimental group reached statistical significance across time, the main effect for time was statistically non-significant for comparison group in terms of TOSRA; Wilks' Lambda = .87, F (2, 39) = 2.81, p = .072, partial eta squared = .13. It means that the attitudes of comparison group students did not change across time (see Table 4.32 for means and standard deviations).

Having obtained statistically significant result from one-way repeated measures ANOVA for experimental group, paired sample t-tests were utilized to check whether there was statistically significant mean difference between pretest to posttest; posttest to follow-up test; and pretest to follow-up test.

4.1.3.3.1.2.1 Pairwise Comparison of TOSRA: Experimental Group

In this part of the result section, the TOSRA scores of experimental group were presented to determine which TOSRA scores differ significantly from each other. Particularly, researcher seeks to find answer to following questions:

1. Is there a significant change in experimental group students' TOSRA scores from pretest to posttest?
2. Is there a significant change in experimental group students' TOSRA scores from posttest to their follow-up test?
3. Is there a significant change from experimental group students' TOSRA scores from pretest to their follow-up test?

Three paired-samples t-test were performed at .008 alpha levels to address abovementioned questions. Table 4.36 shows paired-samples t-test result of experimental group in terms of TOSRA.

Table 4.47 Paired-Samples t-Test Results of TOSRA for Experimental Group

Pairs	t	df	Sig.	Mean Difference	Confidence Interval (99.2 %) Lower	Upper	Eta Squared*
Time 1-Time 2	-5.12	46	.000	-.35	-.54	-.16	.36
Time 2-Time 3	.03	46	.973	.00	-.08	.08	.00
Time 1-Time 3	-5.66	46	.000	-.35	-.52	-.18	.41

*Eta Squared has been calculated using Formula 1.

The first pair at Table 4.36 shows that there was a significant increase in experimental group students' TOSRA scores from pretest (*M* = 3.45, *SD* = .52) to posttest (*M* = 3.80, *SD* = .49); *t* (46) = -5.12, *p* < .0005. The increase in the mean of TOSRA was equal to .35 and the magnitude of this difference was very large with η^2= .36. It points out that HOS instruction has practical value in that it promotes favorable attitudes toward science.

The second pair presented in Table 4.36 reveals that there was no significant change in experimental group students' TOSRA scores from posttest (*M* = 3.80, *SD* = .49) to follow-up test (*M* = 3.80, *SD* = .39); *t* (46) = .03, *p* = .97. This result indicates that the experimental group students' attitudes toward science remained at the same level within the five weeks after the treatment.

The final pair in Table 4.36 indicates that there was a significant increase in experimental group students' TOSRA scores from pretest (*M* = 3.45, *SD* = .52) to follow-up test (*M* = 3.80, *SD* = .39); *t* (46) = -5.66, *p* < .0005. The difference in mean TOSRA score was .35. Eta squared statistic (.41) denotes a large effect size. Overall, pairwise comparisons of experimental group's TOSRA scores revealed that HOS instruction promoted development of more favorable attitudes toward science and these favorable attitudes were retained across five weeks after the treatment.

4.1.3.3.1.2.2 Pairwise Comparison of TOSRA: Comparison Group

Even though multivariate test results of one-way repeated measures ANOVA for comparison group gave non-significant result for the effect of time on TOSRA (see Table 4.35), detailed examination of difference of time pairs may give valuable information on the actual difference among them. Paired sample t-tests were administered among the following pairs: pretest to posttest; posttest to follow-up test; and pretest to follow-up test and the results was evaluated at .008 alpha levels and 99.2 % confidence interval.

Table 4.48 Paired-Samples t-Test Results of TOSRA of Comparison Group

					Confidence Interval (99.2 %)		
Pairs	t	df	Sig.	Mean Difference	Lower	Upper	Eta Squared*
Time 1-Time 2	-1.38	40	.175	-.10	-.30	.10	.05
Time 2-Time 3	-1.65	40	.107	-.06	-.17	.04	.06
Time 1-Time 3	-2.18	40	.035	-.16	-.37	.05	.11

*Eta Squared has been calculated using Formula 1.

The first row at Table 4.37 evaluates the impact of curriculum-oriented instruction on students' TOSRA scores and compares posttest scores to pretest scores of comparison group at .008 alpha levels. There was not a significant increase in TOSRA scores from pretest (M = 3.41, SD = .56) to posttest (M = 3.51, SD = .57); t (40) = -1.38, p = .175. The mean score increase was .10 and eta squared statistics (.05) indicates a small effect size.

What the second row explains is how the scores of comparison group changed five-weeks after the completion of the treatment compared with post-treatment. Interestingly, a slight increase was found from posttest (*M* = 3.51, *SD* = .57) to follow-up test (*M* = 3.57, *SD* = .48). Yet, this increase was not significant statistically; *t* (40) = -1.65, *p* = .064. The mean difference was .16 and eta squared showed a moderate effect size.

The last row at Table 4.37 compares follow-up test result to pretest TOSRA. The result reveals that follow-up test (*M* = 3.57, *SD* = .48) was not significantly different than pretest (*M* = 3.41, *SD* = .56) score of TOSRA for comparison group; *t* (40) = -2.18, *p* = .035. The difference in means scores from pretest to follow-up test is -.16. Eta squared statistic (.11) indicated a medium effect size (see Table 4.32 for means and standard deviations of TOSRA).

4.2 Analysis of Participants' NOS Views

In the current study, students' nature of science views were examined through VNOS-E. In order to provide exhaustive profiles of participants regarding NOS aspects, the findings from between groups and within group comparisons were given for each targeted NOS aspect separately. While creating these profiles, qualitative data were converted to quantitative data as needed. The targeted NOS aspects in this study were as follows:

1. Scientific knowledge is *tentative* that; it is subject to change with new observation and reinterpretation of existing observation.

2. Scientific knowledge is *subjective* that; it is influenced by presently accepted scientific theories and laws; and it also affected by personal subjectivity.
3. Scientific knowledge is *empirical* that; it is based on or derived from observation of the natural world.
4. Scientific knowledge is *creative* and *imaginative* that; its creation involves logical reasoning as well as human imagination.
5. Scientific knowledge is *inferential* that; it is not possible to observe all phenomena in science therefore, it is possible to make logical inferences based on observations.

In an attempt to quantify the qualitative data for each abovementioned NOS aspect, the participants' responses were classified as “naïve”, “transitional”, and “informed” based on the developed rubric (see methodology section for details of the rubric). The reader is reminded that, participants' NOS profiles were created based on their collectivist responses to VNOS-E instead of limiting analysis to one-to-one correspondence between a question on the instrument and a specific aspect of NOS as suggested by Khishfe and Abd-El-Khalick (2002); and Lederman et al., (2002). For example, participants' NOS views regarding empirical aspect were mostly explicated in response to items 1, 2, and 4 on the instrument (see Appendix C). If participants explicated naive, transitional or informed views regarding empirical aspect in any one item and there were no inconsistencies or other disconfirming evidence in their responses to other items regarding this aspect, they were assigned to that level (Khishfe & Abd-El-Khalick, 2002). The following table summarizes the number of item in VNOS-E and the aspect of nature of science it measures.

Table 4.49 The Number of VNOS-E Items and Measured NOS Aspects

Measured Aspect	VNOS-E Item
Tentative	1, 2, 3, 4
Subjective	1, 2, 3, 4, 5, 6
Empirical	1, 2, 4, 5, 6
Creative and Imaginative	1, 4, 5, 6, 7
Inferential	4, 5, 6

In order to ensure confidentiality, the names of the students were not given across the result section. Instead, a coding system was used. In this coding system, each participant identified with a letter followed by a numerical value. Letter indicated participant's group (E represents experimental group, C represents comparison group). The numerical value identified the quoted participant. It changed from 1 to 95; and first 51 numbers were assigned for experimental group (1-51) and next 44 numbers (52-95) were assigned for comparison group. In this coding system, for example, "*E12*" refers to one of the student in "*experimental*" group with "*12*" identification number; while "*C83*" refers to one of the student in "*comparison"* group who has the identification number of "*83*".

4.2.1 Between Group Comparisons of Participant's NOS Views

During the between group comparisons, following research question was investigated:

"What are the differences between HOS instruction group and curriculum-oriented instruction group with respect to targeted NOS aspects at pre-instruction, post-instruction, and follow-up measurements?"

In order to address this research question, experimental and comparison group students' pre-instruction, post-instruction, and follow-up NOS views were analyzed and the results were reported for each targeted NOS aspect separately.

4.2.1.1 Comparison of Groups' Pre-Instruction NOS Views

4.2.1.1.1 Comparison of Groups' Pre-Instruction NOS Views Regarding Tentative Aspect

The following part presented experimental and comparison group participants' profiles of pre-instruction NOS views regarding tentative aspect. To make the presentation coherent, the percent of participants in each level (i.e. naïve, transitional and informed), related assumption checking and the result of test were exhibited sequentially.

The following figure (Figure 4.3) presents the percent of participants in each level. As shown in the bar graph students in both group demonstrated similar understandings across each level.

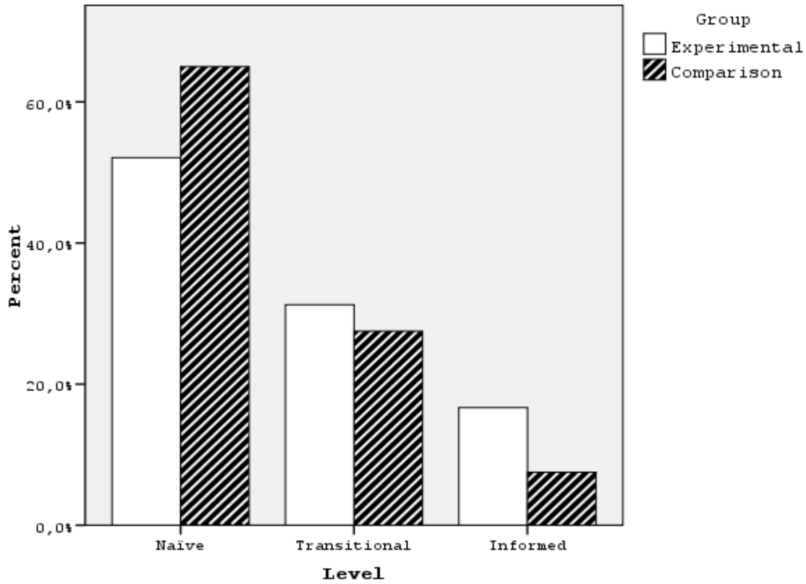

Figure 4.3 Participants' Pre-instruction Views Regarding Tentative Aspect (%)

In fact, prior to instruction only 3 (8%) students in comparison group and 8 (17%) students in experimental group exhibited an informed views of tentative NOS. In turn,15 (31%) students in experimental group and 11 (28%) students in comparison groups revealed transitional views. In terms of naïve views, there were 25 (52%) students in experimental group and 26 (65%) students in comparison group.

Bar graph (Figure 4.3) did not indicate considerable difference between the groups. To test the statistical significance, Contingency Table Analysis (Pearson Chi-square Test) was conducted and the results were tabulated below (4.39). Before presenting the result of the test, the assumption for the chi-square test was reported. Yates, Moore and McCabe (1999) stated that in order to conduct chi-square test there should be "No more than 20% of the expected counts are less than 5" (p. 734). The assumption test indicated that minimum expected count for tentative aspect was 5.00. This means that there is no expected cell sizes less than 5, so the assumption was met for chi-square test. Therefore it was safe to interpret the result of the chi-square test.

Table 4.50 Chi-square Test Results Regarding Tentative Aspect Prior to the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Tentative	2.20	.333	.16

As seen in Table 4.39, the significance value is .333 which is greater than critical point of .05. In other words it was not significant. Moreover the effect size is .16 which indicates small effect size (Cohen, 1988). As a result, it can be concluded that prior to instruction there was not statistically significant differences in proportions regarding naïve, transitional, and informed views between experimental and comparison group in terms of tentative aspect of NOS, χ^2 (2, n = 88) = 2.20, p = .333, Cramer's V = .16.

4.2.1.1.2 Comparison of Groups' Pre-Instruction NOS Views Regarding Subjective Aspect

This part presents experimental and comparison group participants pre-instruction NOS views regarding subjective aspect. Figure 4.4 shows the percentages of participants in each level (naïve, transitional and informed). As seen in the figure, most of the participants articulated naïve or transitional views at both group. Specifically, more than half of the participants (22 out of 40) in comparison group and 40 percent of participants (19 out of 48) in experimental group demonstrated naïve views regarding subjective aspect of NOS. Similarly, 20 (42%) students in experimental group and 13 (33%) students in comparison groups held transitional subjective views. Only 9 (19%) students in experimental group and 5 (13%) students in comparison group perceived informed views regarding subjective aspect of NOS.

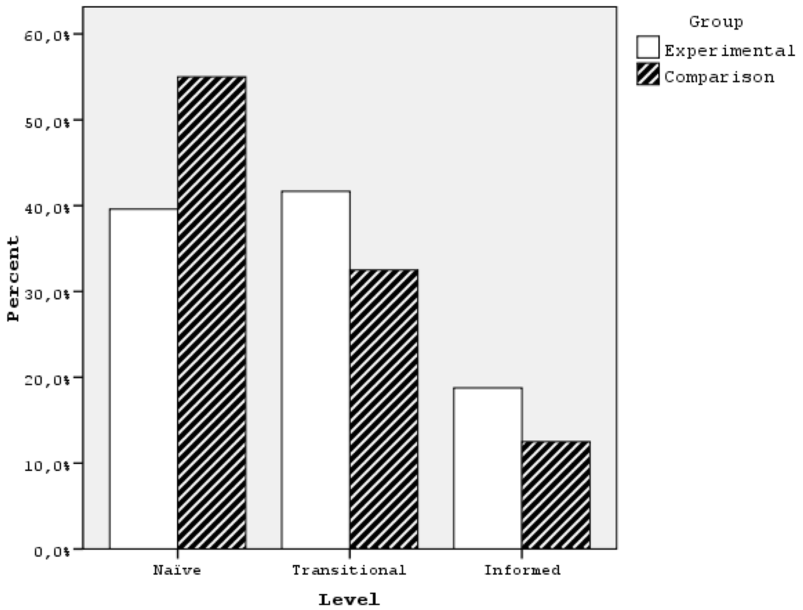

Figure 4.4 Participants' Pre-instruction Views Regarding Subjective Aspect (%)

The assumption checking for the chi-square test indicated that minimum expected count was 6.36. This means that expected cell sizes was greater than 5 so the assumption was met for chi-square test. Therefore it was safe to interpret the result of the chi-square test. Table 4.40 illustrates the result of Chi-square test.

Table 4.51 Chi-square Test Results Regarding Subjective Aspect Prior to the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Subjective	2.14	.343	.16

The chi-square test did not yield significant results with small effect size. Therefore it is reasonable to conclude that prior to instruction there was not statistically significant differences in proportions regarding naïve, transitional, and informed views between experimental and comparison group in terms of the subjective aspect of NOS, χ^2 (2, n = 88) = 2.14, p = .343, Cramer's V = .16.

4.2.1.1.3 Comparison of Groups' Pre-Instruction NOS Views Regarding Empirical Aspect

In this part, the comparison of groups' pre-instruction NOS understanding were presented with respect to empirical tenet. In line with the previous two parts, the percent of participants in each level was presented through bar graph first (Figure 4.5). The bar graph indicated that the largest percent of experimental group students expressed transitional views while comparison group students hold informed views mostly.

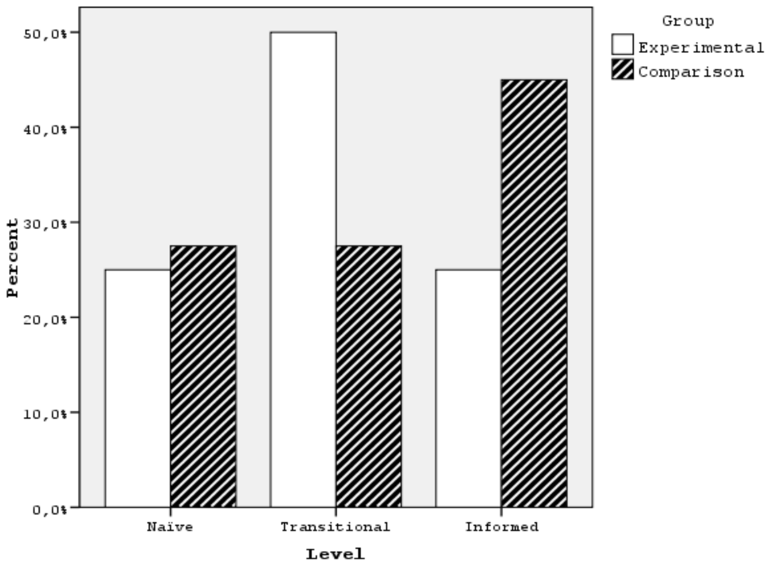

Figure 4.5 Participants' Pre-instruction Views Regarding Empirical Aspect (%)

In particular, as shown in the Figure 4.5, while almost half of the participants (18 out of 40) in comparison group and 25 percent of participants (12 out of 48) in experimental group demonstrated informed empirical views. In terms of transitional views, there were 24(50%) students in experimental group and 11 (28%) students in comparison group. However, twelve (25%) students in experimental group and 11 (28%) students in comparison group articulated naïve empirical views.

Before reporting the result of the test, which investigated statistical significant difference between the groups, the assumption for the chi-square test was provided. The result indicated that minimum expected count for empirical aspect was 10.45. This means that expected cell sizes was greater than 5 so the assumption was met for chi-square test. Therefore it can be concluded that there is not an important treat for the validity of conclusions drawn from statistical analysis result (Table 4.41).

Table 4.52 Chi-square Test Results Regarding Empirical Aspect Prior to the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Empirical	5.39	.068	.247

Table 4.41 indicates that the significance value is .068 which is greater than critical point of .05; implying a non-significant relationship. Moreover the effect size is less than .30. According to Cohen (1988) this is the indication of small effect size. Consequently, it can be concluded that prior to instruction there was not statistically significant differences in the proportions of participants who articulated naïve, transitional, and informed views between experimental and comparison group in terms of the empirical aspect of NOS, χ^2 (2, n = 88) = 5.39, p = .068, Cramer's V = .25.

4.2.1.1.4 Comparison of Groups' Pre-Instruction NOS Views Regarding Creative and Imaginative Aspect

The comparison of the two groups' profiles of pre-instruction NOS views regarding creative and imaginative aspect were introduced in this part. Figure 4.6 shows the percentages of participants in each level. It shows that 15 (31%) students in experimental group and 14 (35%) students in comparison group revealed a naïve view. Similarly, 21 (44%) students in experimental group and 16 (40%) students in comparison groups demonstrated transitional creative and imaginative views. In turn, 12 (25%) students in experimental group and 10 (25%) students in comparison group reflected their informed understandings prior to instructions.

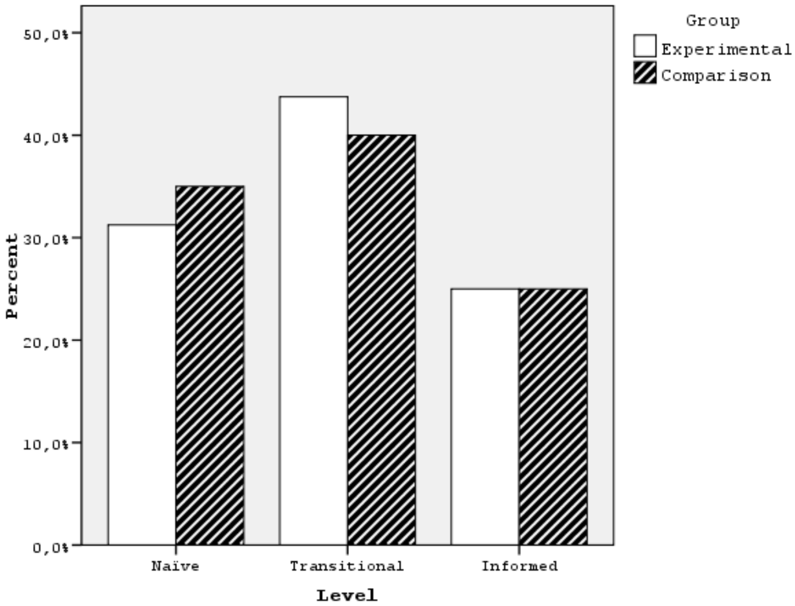

Figure 4.6 Participants' Pre-instruction Views Regarding Creative and Imaginative Aspect (%)

The result of assumption checking indicated that minimum expected count for creative and imaginative aspect was 10.00, indicating that the assumption was met for chi-square test. Therefore it was safe to interpret the result of the chi-square test. Table 4.42 shows the result of it.

Table 4.53 Chi-square Test Results Regarding Creative and Imaginative Aspect Prior to the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Creative and Imaginative	.17	.920	.04

As seen in Table 4.42, the chi-square test did not yield significant results with small effect size, χ^2 (2, n = 88) = .17, p = .920, Cramer's V = .04. Therefore it is reasonable to conclude that prior to instruction there was not statistically significant differences in the proportions of participants who articulated naïve, transitional, and informed views between experimental and comparison group in terms of the creative and imaginative aspect of nature of science.

4.2.1.1.5 Comparison of Groups' Pre-Instruction NOS Views Regarding Inferential Aspect

Regarding inferential aspect of NOS, this part presents the experimental and comparison group participants' NOS understanding before the instructions. Figure 4.7 shows the percentages of participants in each level. The figure indicates that a substantial amount of students in both groups expressed naïve views. In this respect, 36 (75%) students in experimental group and 29 (73%) students in comparison group held naïve views. On the other hand, 7 (15%) students in experimental group and 5 (13%) students in comparison groups held transitional inferential views. Only five (10%) students in experimental group and 6 (15%) students in comparison group, however, demonstrated an informed views regarding inferential aspect of NOS.

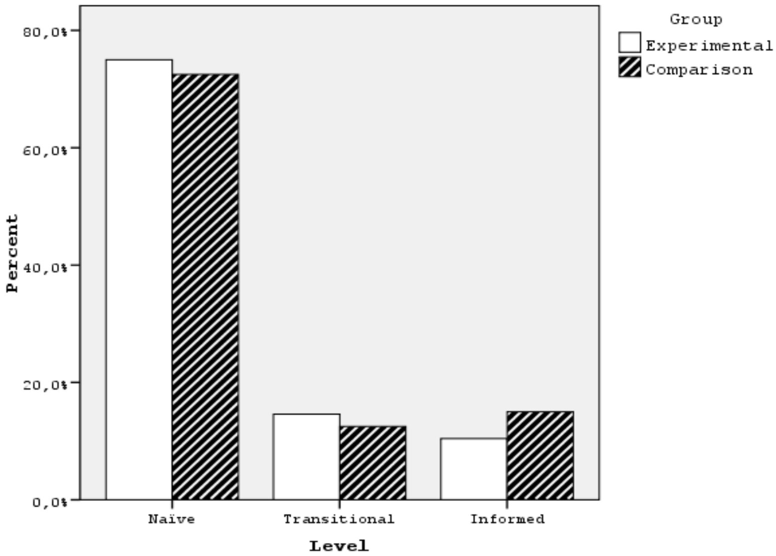

Figure 4.7 Participants' Pre-instruction Views Regarding Inferential Aspect (%)

Before discussing the result of statistical test, the assumption for the chi-square test was reported. The result indicated that minimum expected count for inferential aspect was 5.00 meaning that the assumption was met for chi-square test. Therefore it was safe to interpret the result of the chi-square test (Table 4.43).

Table 4.54 Chi-square Test Results Regarding Inferential Aspect Prior to the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Inferential	.46	.797	.07

Table 4.43 illustrates that the chi-square test did not yield significant results, χ^2 (2, *n* = 88) = .46, *p* = .797, Cramer's *V* = .04. Therefore it can be concluded that prior to instruction there was not statistically significant differences in proportions

regarding naïve, transitional, and informed views between experimental and comparison group in terms of the inferential aspect of NOS.

So far, experimental and comparison group students' understanding of nature of science were discussed by taking into account of their understanding before curriculum-oriented and history of science instruction. It was found that there was not a significant difference between the groups. In the next part, their post-instruction understanding were presented.

4.2.1.2 Comparison of Groups' Post-Instruction NOS Views

4.2.1.2.1 Comparison of Groups' Post-Instruction NOS Views Regarding Tentative Aspect

In this part of the result, the comparisons of students' tentative views in both groups were explained in terms of their post-instruction views. The percents of participants in the levels were presented in Figure 4.8.

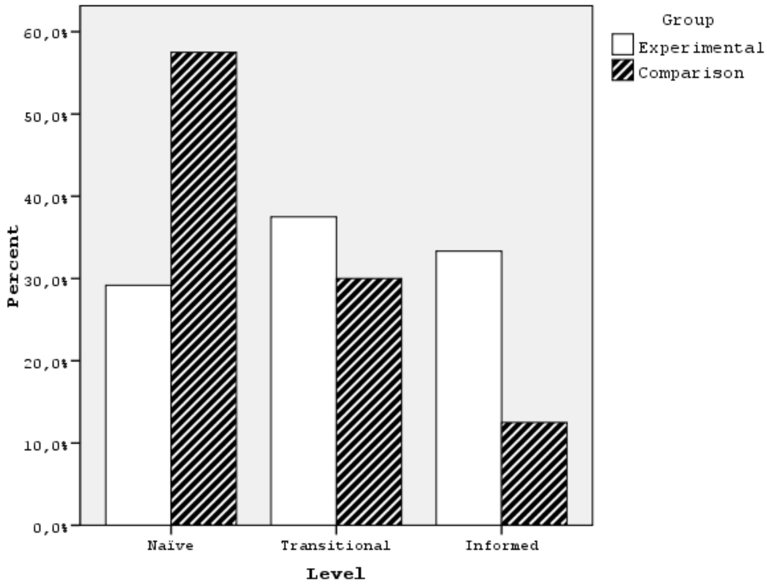

Figure 4.8 Participants' Post-instruction Views Regarding Tentative Aspect (%)

Figure 4.8 shows that 16 (33%) students in experimental group and 5 (13%) students in comparison group perceive the notion that scientific knowledge is subject to change. The response of18 (38%) students in experimental group and 12 (30%) students in comparison groups reflected their transitional tentative views. On the other hand, 14 (29%) students in experimental group and 23 (58%) students in comparison group revealed a naïve views.

To test the difference between the groups statistically, Contingency Table Analysis was performed. Before tabulating the result of the test the assumption for the chi-square test indicated that minimum expected count for tentative aspect was 9.55. This means that assumption was met for chi-square test. Table 4.44 summarizes the result of Chi-square test.

Table 4.55 Chi-square Test Results Regarding Tentative Aspect Right After the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Tentative	8.42	.015	.31

As seen in Table 4.44, statistical comparison yielded a significant difference with *p* = .015. It means that, at least in one level, the proportions of participants in the groups were significantly different than each other right after the instructions, χ^2 (2, *n* = 88) = 8.42, *p* = .015. The magnitude of this difference was medium, Cramer's *V* = .31.

In order to find out the level (or levels) the groups differ, separate chi-square tests was performed. In other words, the proportion of participant in both groups was compared for each level (naïve, transitional, and informed) separately. In this comparison, Yates' continuity correction for statistical significance and phi coefficient for effect size were reported in order to compensate for overestimation of chi-square test. Before conducting chi-square test for the levels, the assumption was checked and the outcome were reported. The minimum expected counts were found as 16.82, 13.64, and 9.55 for naïve, transitional and informed level respectively. Therefore there was not any expected count less than 5; meaning that the assumption was met. Hence it is safe to interpret the chi-square result.

Table 4.56 Chi-square Test Results of Levels for Tentative Aspect of NOS at Posttest

Category	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	6.072	.014	-.286
Transitional	0.263	.608	.079
Informed	4.128	.042	.243

Table 4.45 reveals that the proportion of participants in experimental group who elucidated naïve views was significantly lower than comparison group, χ^2 (1, n = 88) = 6.07, p = .014. The degree of this proportion difference was roughly medium, phi = -.29. Actually 58 percent of total participant in comparison group expressed naïve views while this percent was just 29 in experimental group at posttest.

In the transitional level, though, there was no significant difference, χ^2 (1, n = 88) = .26, p = .61, phi = .08. In fact 38 percent of participants in experimental group and 30 percent of comparison group reflected a transitional views about tentative aspect of NOS after the instructions.

In informed level, the proportion of participants in experimental group was significantly higher than comparison group, χ^2 (1, n = 88) = 4.13, p = .042. The magnitude of this proportion difference was small, phi = .24. While 33 percent of participant in experimental group demonstrate an informed view of tentative aspect of NOS, only 13 percent of participants in comparison group reflected an informed understanding of tentative NOS.

4.2.1.2.2 Comparison of Groups' Post-Instruction NOS Views Regarding Subjective Aspect

In this part, the comparisons of students' subjective views were discussed in terms of their post-instruction views. Figure 4.9 illustrates the percent of participants in each group.

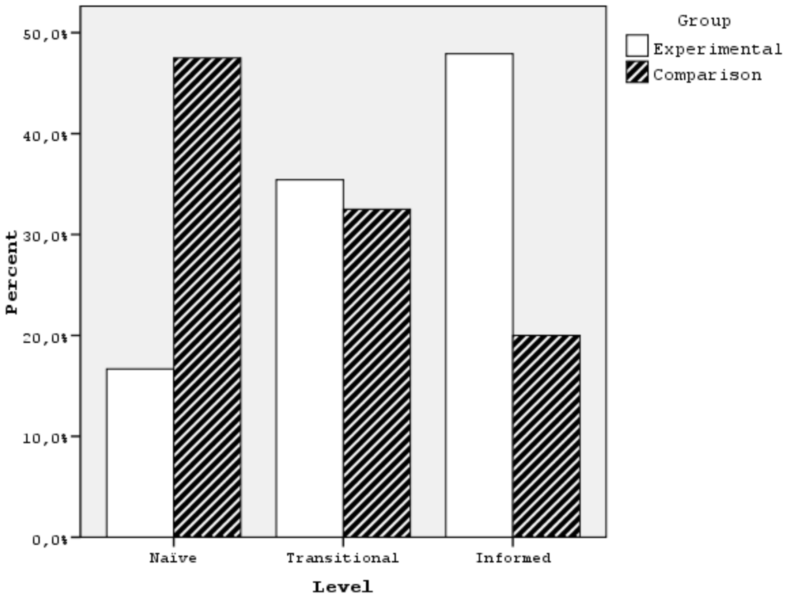

Figure 4.9 Participants' Post-instruction Views Regarding Subjective Aspect (%)

The bar graph shows that there were noticeably different amount of participants especially in naïve and informed level. Close examination of bar graph indicated that twenty-three (48%) students in experimental group and only 8 (20%) students in comparison group exhibit an informed views after the instructions. Accordingly, 17 (35%) students in experimental group and 13 (33%) students in comparison groups demonstrated transitional subjective views. In response, 8 (17%) students in experimental group and 19 (48%) students in comparison group were exhibited a naïve views regarding subjective aspect of NOS after the instructions.

It was evident that students in experimental group held more informed views and less naïve views about subjective aspect of NOS when compared to the students in comparison group. To test the difference between groups another Contingency Table Analysis was performed. Before providing the result of the test the assumption for the chi-square test was given. The result indicated that minimum expected count for subjective aspect was 12.27. This means that assumption was met. Table 4.46 summarizes the result of Chi-square test.

Table 4.57 Chi-square Test Results Regarding Subjective Aspect Right After the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Subjective	11.61	.003	.36

As seen in Table 4.46, the proportions of participants in both group who articulated naïve, transitional or informed views were significantly different than each other right after the instruction, χ^2 (2, n = 88) = 11.61, p = .003. The magnitude of this difference was medium, Cramer's V = .36.

In order to find out the sources of difference between the groups, separate chi-square tests were performed. Before discussing the chi-square test result, the assumption was given. The minimum expected count was found to be 12.27, 13.64, and 14.09 for naïve, transitional and informed levels respectively. Therefore there were not any expected counts less than 5; meaning that the assumption was met.

Table 4.58 Chi-square Test Results of Levels for Subjective Aspect of NOS at Posttest

	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	8.36	.004	-.33
Transitional	.00	.951	.03
Informed	6.28	.012	.29

From Table 4.47, it can be deduced that the proportion of participants in comparison group who had naïve views regarding subjective aspect of NOS was significantly higher than experimental group, χ^2 (1, n = 88) = 8.36, p = .004. The magnitude of this difference was medium, phi = -.33. The participants in comparison group holding naïve views was 48 percent of their group, while just 17 percent of participant in experimental group maintained naïve views about subjective nature of science.

There was not a significant difference in the proportion of participants in both groups who held transitional views about subjective aspect of NOS, χ^2 (1, n = 88) = .004, p = .95, phi = .03. Overall, 35 percent of experimental group and 33 percent of comparison group elucidated transitional views.

The number of participants who demonstrated an informed understanding of subjective NOS in experimental group was significantly higher than comparison group regarding right after the instruction, χ^2 (1, n = 88) = 6.28, p = .012. The degree of this difference was close to medium, phi = .29. After the instruction more than twice of the participants were holding informed views about subjective aspect of NOS. In fact, the percent of participant at experimental group were 48 while the percent of participant at comparison group were 20 in terms of informed views on subjective NOS.

4.2.1.2.3 Comparison of Groups' Post-Instruction NOS Views Regarding Empirical Aspect

This part presented experimental and comparison group participants' post-instruction NOS profiles about empirical aspect. To be consistent, same sequence of presentation was followed with the previous parts. Figure 4.10 presents the percentages of participants' post-instruction views.

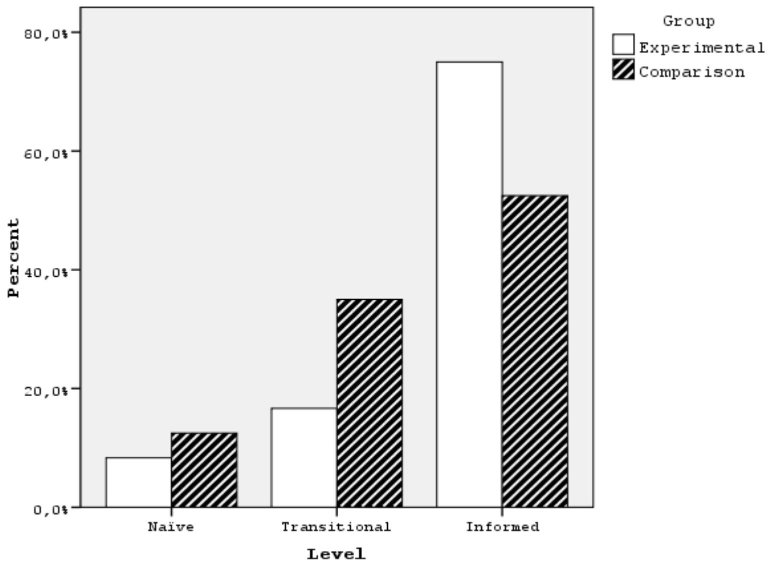

Figure 4.10 Participants' Post-instruction Views Regarding Empirical Aspect (%)

As seen in the bar graph, although sizable amount of participants in both group elucidated informed view, more participants in experimental group expressed an informed understanding. Actually, thirty-six (75%) students in experimental group and 21 (53%) students in comparison group reflected their informed understanding of empirical NOS. However, only eight (17%) students in experimental group and

14 (35%) students in comparison groups elucidated transitional views. Likewise, there were just 4 (8%) students in experimental group and 5 (13%) students in comparison group holding naïve views.

Figure 4.10 revealed that after the instructions students in both groups exhibited more informed views and less naïve views about empirical aspect of NOS. To test the difference between the groups statistically, Contingency Table Analysis was performed and result were reported below (Table 4. 48). But before presenting it, the result for the assumption of the chi-square test indicated that minimum expected count for empirical aspect was 4.09 and 33% of expected count were less than 5. This means that assumption was not met for chi-square test. In such case, it is suggested that Fisher's exact test statistics should be reported instead of chi-square statistics. Hence it was reported for chi-square test.

Table 4.59 Chi-square Test Results Regarding Empirical Aspect Right After the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Empirical	4.98	.076	.239

As seen in Table 4.48, the proportions of participants' naïve, transitional and informed views of experimental group regarding empirical aspect of NOS was not significantly different than comparison group right after the instruction, χ^2 (2, n = 88) = 4.98, p = .076, Cramer's V = .24.

4.2.1.2.4 Comparison of Groups' Post-Instruction NOS Views Regarding Creative and Imaginative Aspect

This part reports the results of the participants' creative and imaginative views in terms of their post-instruction views. Figure 4.11 presents the percentages of participants' level by level.

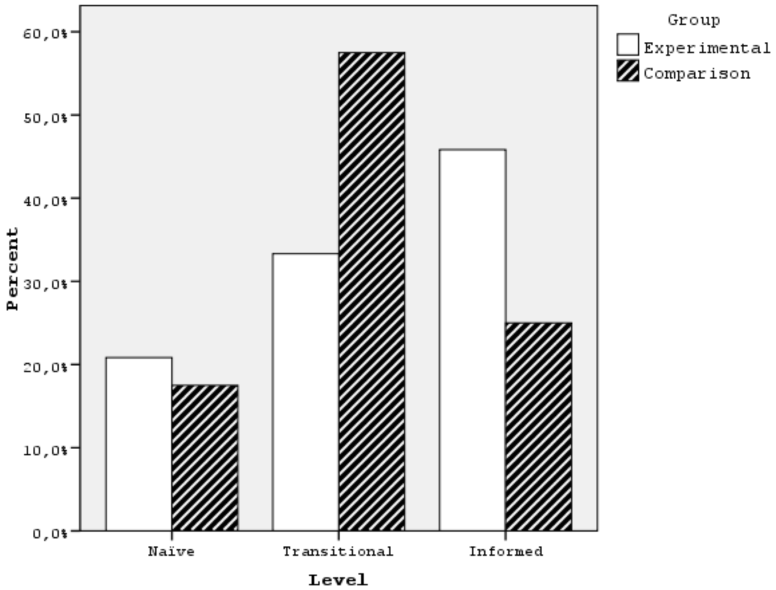

Figure 4.11 Participants' Post-instruction Views Regarding Creative and Imaginative Aspect (%)

Figure 4.11 shows that noticeably different amount of participants in both group expressed informed and transitional views after the instructions. Twenty-two (46%) students in experimental group and 10 (25%) students in comparison group held informed views. On the other hand, there were 16 (33%) students in experimental group and 23 (58%) students in comparison expressing a transitional views. In turn, 10 (21%) students in experimental group and 7 (48%) students in comparison group, reflected their naïve understanding after the instructions.

The bar graph indicated that after instruction students in experimental group held more informed views and less transitional views than students in comparison group. Contingency Table Analysis (Pearson Chi-square Test) was performed to assess whether these difference is statistically significant. Preliminary analysis indicated that minimum expected count for creative and imaginative aspect was 7.73. This means that assumption was met. Table 4.49 summarizes the result of Chi-square test.

Table 4.60 Chi-square Test Results Regarding Creative and Imaginative Aspect Right after the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Creative and Imaginative	5.55	.063	.25

As seen in Table 4.49, the proportions of participants' naïve, transitional and informed views of experimental group regarding creative and imaginative aspect of NOS was not significantly different than comparison group right after the instruction, χ^2 (2, n = 88) = 5.55, p = .063. The magnitude of this difference was small, Cramer's V = .25.

4.2.1.2.5 Comparison of Groups' Post-Instruction NOS Views Regarding Inferential Aspect

Regarding inferential NOS, this part presents experimental and comparison group participants post-instruction views. Figure 4.12 presents the proportion of participants' post-instruction views in each level.

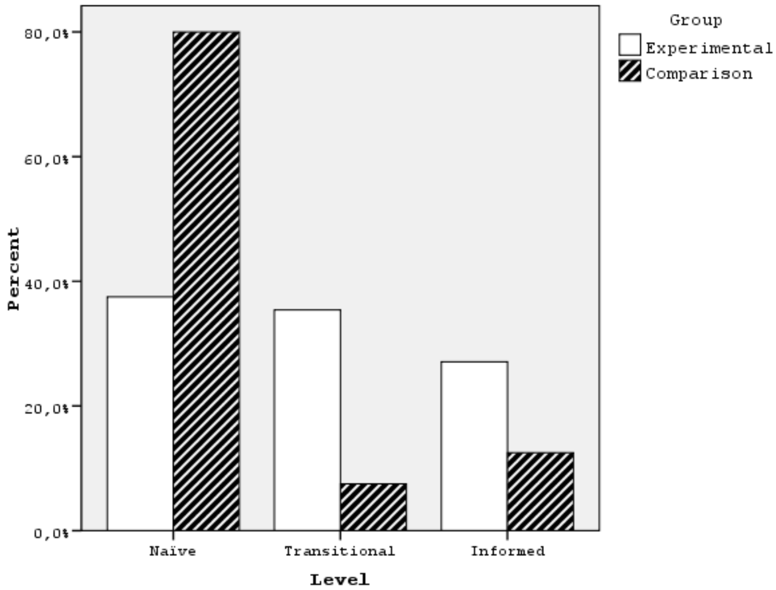

Figure 4.12 Participants' Post-instruction Views Regarding Inferential Aspect (%)

Figure 4.12 shows that noticeably different amount of participants in each group articulated naïve and transitional views after the instructions. Eighteen (38%) students in experimental group and 32 (80%) students in comparison group exhibited naïve views, while 17 (35%) students in experimental group and 3 (8%) students in comparison groups revealed a transitional inferential views. On the other hand, 13 (27%) students in experimental group and 5 (13%) students in comparison group demonstrated an informed understanding after the instructions.

Before presenting the result of test which assessed this difference statistically, the assumption checking indicated that minimum expected count was 8.18. This means that there is no violation of the assumption. The result of Chi-square test was given in Table 4.50.

Table 4.61 Chi-square Test Results Regarding Inferential Aspect Right After the Instructions

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Inferential	16.89	.000	.44

Table 4.50 displays that the proportions of participants in experimental group who hold naïve, transitional or informed views was significantly different than comparison group right after the instructions, χ^2 (2, n = 88) = 16.89, p < .0005. The magnitude of this difference was medium, Cramer's V = .44.

In order to explore the levels in which experimental and comparison group students' views differed, separate chi-square tests were performed. Again, preliminary analyses showed that the minimum expected cell frequencies for naïve, transitional, and informed levels were 17.27, 9.09, and 8.18 respectively. It means that there were not a violation of the assumption for chi-square tests.

Table 4.62 Chi-square Test Results of Levels for Inferential Aspect of NOS Right After the Instructions

	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	14.38	.000	-.43
Transitional	8.16	.004	.33
Informed	2.03	.155	.18

Table 4.51 illustrates that the proportion of participants in experimental group who elucidated a naïve views was substantially lower than comparison group at posttest, χ^2 (1, n = 88) = 14.38, p < .0005. The degree of this proportion difference is close to large, phi = -.43.

There was also a statistically significant difference between the groups who have transitional views about inferential aspect of NOS, χ^2 (1, n = 88) = 8.16, p = .004. The magnitude of this percent difference among groups was medium, phi = .33.

However, the proportion of participants in informed level was not significantly different than each other between the groups, χ^2 (1, n = 88) = 2.03, p = .155, phi = .18.

4.2.1.3 Comparison of Groups' Follow-up NOS Views

4.2.1.3.1 Comparison of Groups' Follow-up NOS Views Regarding Tentative Aspect

In this part of the result section, the comparison of groups' follow-up NOS views were discussed. Figure 4.13 reveals the percentages of participants' follow-up views regarding tentative aspect of NOS.

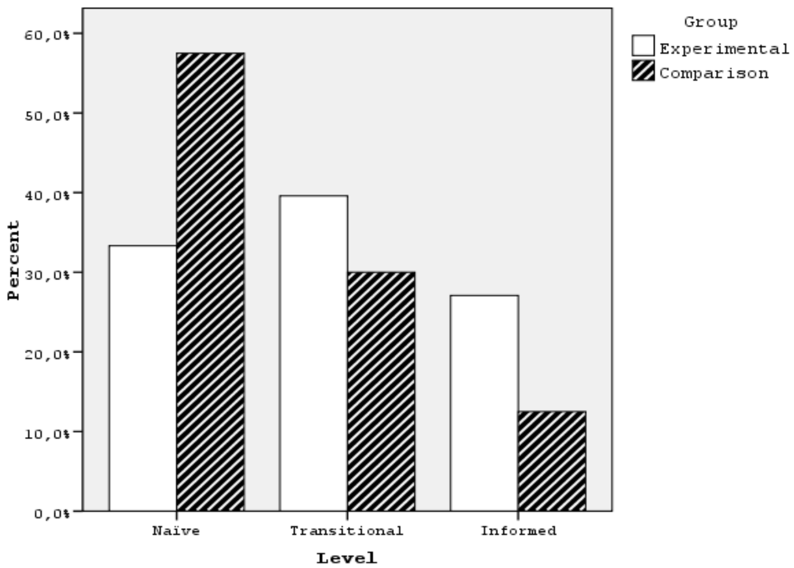

Figure 4.13 Participants' Follow-up Views Regarding Tentative Aspect (%)

Figure 4.13 shows that 13 (27%) students in experimental group and 5 (13%) students in comparison group expressed an informed views while 19 (40%) students in experimental group and 12 (30%) students in comparison groups demonstrated transitional tentative views. However, 16 (33%) students in experimental group and 23 (58%) students in comparison group were holding naïve views at follow-up measurement.

To figure out the statistical meanings of the difference, the result of Contingency Table Analysis was tabulated (Table 4.52). Also, inspection of minimum expected count revealed no violation of the assumption (8.18).

Table 4.63 Chi-square Test Results Regarding Tentative Aspect at Follow-up

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Tentative	5.59	.061	.26

Table 4.52 indicated no significant difference between experimental and comparison group regarding tentative aspect of NOS at follow-up measurement, χ^2 (2, n = 88) = 5.59, p = .061, Cramer's V = .26.

4.2.1.3.2 Comparison of Groups' Follow-up NOS Views Regarding Subjective Aspect

In this part, groups' follow-up NOS views regarding subjective aspect were presented based on follow-up measurement. Figure 4.14 reveals the percentages of participants in each level.

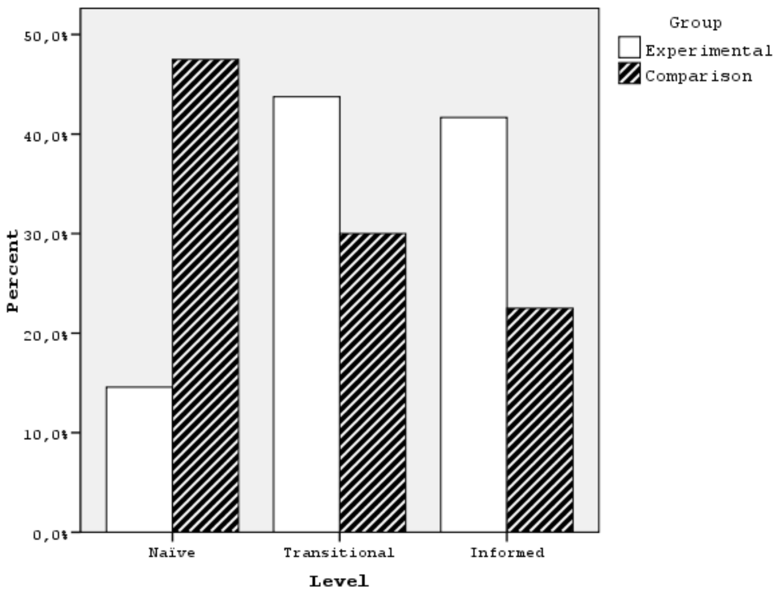

Figure 4.14 Participants' Follow-up Views Regarding Subjective Aspect (%)

As shown in the bar graph above, the number of participants in each level differed substantially. Detailed examination of the data showed that 20 (42%) students' response in experimental group and 9 (23%) of comparison group reflect their informed understanding where 21 (44%) students in experimental group and 12 (30%) students in comparison groups articulated transitional subjective views. Yet, 7 (15%) students in experimental group and 19 (48%) students in comparison group were still holding naïve subjective views at follow-up.

Contingency Table Analysis (Pearson Chi-square Test) was conducted to investigate whether the groups differed statistically in terms of their subjective views at follow-up measurement. Preliminary analysis indicated no violation about minimum expected count (11.82). The following bar graph (Table 4.53) tabulates the result of Chi-square test.

Table 4.64 Chi-square Test Results Regarding Subjective Aspect at Follow-up

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Subjective	11.40	.003	.36

As seen in Table 4.53, the proportions of participants' naïve, transitional and informed views of experimental group regarding subjective aspect of NOS was significantly different than comparison group at follow-up, χ^2 (2, n = 88) = 11.40, p = .003. The magnitude of this difference was medium, Cramer's V = .36.

In order to find out where the difference occurred, separate chi-square tests were performed for each level. The minimum expected cell frequencies were 11.82, 15.00, and 13.18 for naïve, transitional and informed levels respectively. This indicated that there were no violation of the assumption of chi-square tests. Hence it was secure to interpret chi-square test results.

Table 4.65 Chi-square Test Results of Levels for Subjective Aspect of NOS at Follow-up

	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	9.830	.002	-.359
Transitional	1.222	.269	.141
Informed	2.812	.094	.203

Five weeks after the intervention, a significant proportion of participants at comparison group held naïve views regarding subjective aspect of NOS when compared to experimental group, χ^2 (1, n = 88) = 9.83, p = .002. The degree of this difference was medium, phi = -.36. Almost half of the participants at comparison group were holding naïve views about subjective aspect of NOS while just 1 of every seven individual at experimental group was holding naïve views regarding same aspect.

There was no significant difference in the proportions of participants the groups who revealed transitional views, χ^2 (1, n = 88) = 1.22, p = .269, phi = .14. Forty four percent of participants in experimental group and 30 percent of participants in comparison group hold transitional views.

Taken into account of the proportions of participants who expressed informed views, experimental group did not differ significantly than comparison group, χ^2 (1, n = 88) = 2.81, p = .094, phi = .20.

4.2.1.3.3 Comparison of Groups' Follow-up NOS Views Regarding Empirical Aspect

The following part describes the groups' follow-up NOS views regarding empirical aspect.

According to Figure 4.15 most of the participants in experimental group were informed about empirical aspect of NOS. Thirty-three (69%) students in experimental group and 19 (48%) students in comparison group elucidated informed views. In response, 11 (23%) students in experimental group and 17 (43%) students in comparison groups indicated transitional empirical views. Accordingly, 4 (8%) students in experimental group and 4 (10%) students in comparison group expressed naïve views.

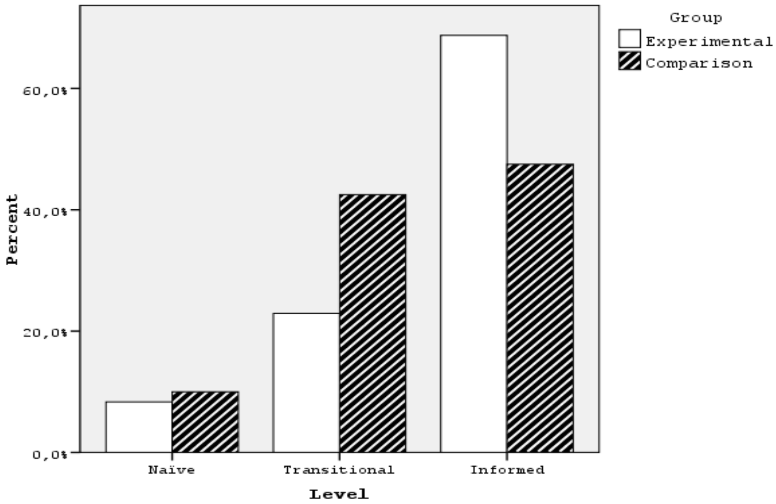

Figure 4.15 Participants' Follow-up Views Regarding Empirical Aspect (%)

After briefly mentioning about the percent of participants in each level, the results of Contingency Table Analysis were tabulated below (Table 4.55) to compare the groups' follow-up empirical views statistically.

Before interpreting the result of the chi-square test, the assumption for the chi-square test was provided. It was found that minimum expected count for empirical aspect was 3.64 and 33% of expected count were less than 5. This means that the data did not meet the required assumption for chi-square test. Therefore, Fisher's exact test statistics was reported to compensate it.

Table 4.66 Chi-square Test Results Regarding Empirical Aspect at Follow-up

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Empirical	4.37	.098	.223

Table 4.55 indicated that the proportions of participants' naïve, transitional and informed views of experimental group regarding empirical aspect of NOS was not

significantly different than comparison group at follow-up measurement, χ^2 (2, n = 88) = 4.37, p = .098, Cramer's V = .22. It means that participants' follow-up NOS views between groups were comparable at each level (i.e. naïve, transitional and informed) regarding empirical NOS.

4.2.1.3.4 Comparison of Groups' Follow-up NOS Views Regarding Creative and Imaginative Aspect

During the following part, the groups' creative and imaginative NOS views were presented by comparing their follow-up views. The percent of participants in each level were shown in Figure 4.16.

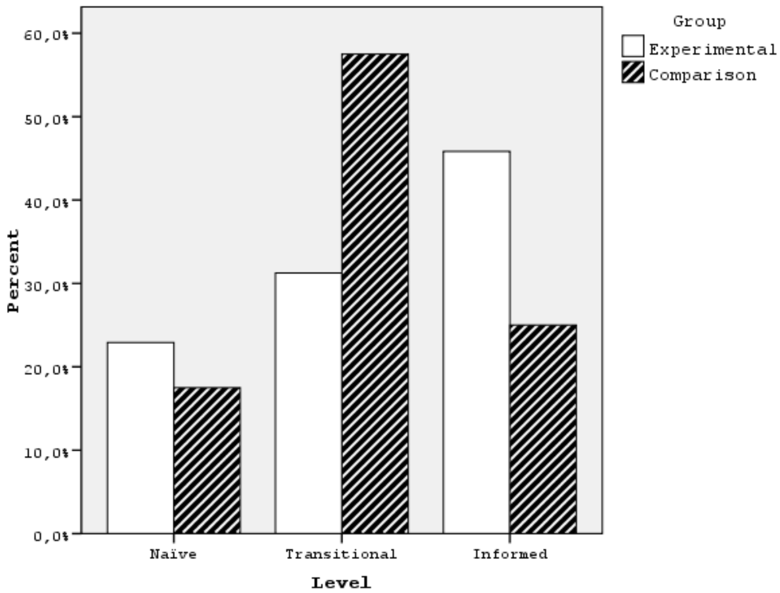

Figure 4.16 Participants' Follow-up Views Regarding Creative and Imaginative Aspect (%)

The bar graph shows that 22 (46%) students in experimental group and 10 (25%) students in comparison group demonstrated informed views while 15 (31%) students in experimental group and 23 (58%) students in comparison groups articulated transitional creative and imaginative views. On the other hand,11 (23%) students in experimental group and 7 (18%) students in comparison group elucidated naïve views at follow-up measurement.

To express the statistical significance of the difference between groups, the result of Contingency Table Analysis (Pearson Chi-square Test) was tabulated below (Table 4.56). Assumption testing indicated that minimum expected count for creative and imaginative aspect was 8.18. This means that assumption was met for chi-square test.

Table 4.67 Chi-square Test Results Regarding Creative and Imaginative Aspect at Follow-up

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Creative and Imaginative	6.31	.046	.27

According to Table 4.56, the proportions of participants' naïve, transitional and informed views of experimental group was significantly different than comparison group at follow-up, χ^2 (2, n = 88) = 6.31, p = .046. The magnitude of this difference was small, Cramer's V = .27.

In order to find out where the difference lies, chi-square tests were performed for each level separately. The minimum expected frequencies were found to be 8.18, 17.27, and 14.55 for naïve, transitional and informed levels respectively. This indicated that there were no violation of the assumption of chi-square tests.

Table 4.68 Chi-square Test Results of Levels for Creative and Imaginative Aspect of NOS at Follow-up

	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	.13	.717	-.07
Transitional	5.10	.024	-.26
Informed	3.24	.072	.22

Five weeks after the intervention, there was a significant difference only in proportion of participants expressing transitional views, χ^2 (1, n = 88) = 5.10, p = .024. The degree of this difference was small, phi = -.26. The result showed that more participants in comparison group (58%) held transitional creative and imaginative views than the participants in experimental group (31%).

At follow-up measurement, there was no significant difference in the proportions of participants in experimental group and in comparison group who had naïve views, χ^2 (1, n = 88) = .13, p = .717, phi = -.07; and informed views χ^2 (1, n = 88) = 3.24, p = .072, phi = .22 about creative and imaginative aspect of NOS.

4.2.1.3.5 Comparison of Groups' Follow-up NOS Views Regarding Inferential Aspect

Throughout this part, the comparison of participants' inferential views were presented in terms of their follow-up views. Actually, there seemed to have a major differences between the groups at five-week follow-up measurement (see Figure 4.17).

Figure 4.17 shows that 16 (33%) students in experimental group and 31 (78%) students in comparison group elucidated naïve views where 19 (40%) students in experimental group and 4 (10%) students in comparison groups held transitional inferential views. Thirteen (27%) students in experimental group and 5 (13%) students in comparison group, though, expressed informed views.

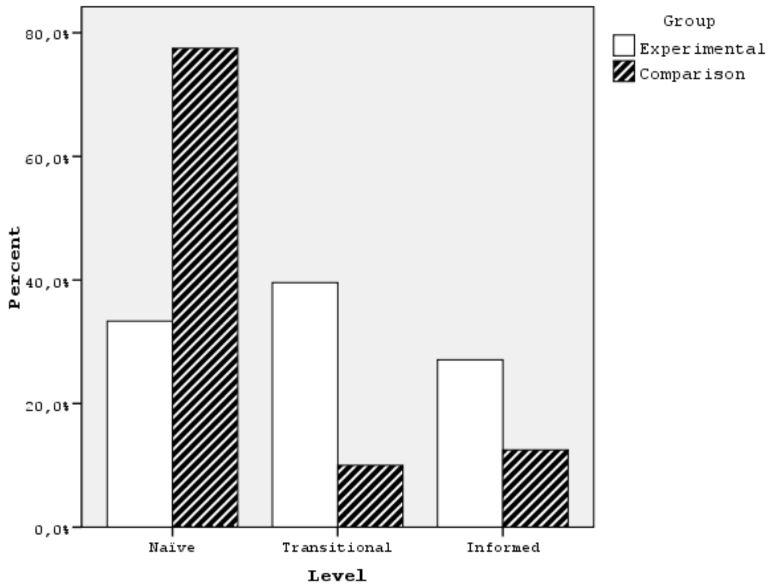

Figure 4.17 Participants' Follow-up Views Regarding Inferential Aspect (%)

To test the statistical significance of this difference, Contingency Table Analysis (Pearson Chi-square Test) was performed and the result was tabulated (Table 4.58). But, before providing the result of the test, the assumption for the chi-square test was given. The result indicated that minimum expected count for inferential aspect was 8.18. This means that assumption was met for chi-square test.

Table 4.69 Chi-square Test Results Regarding Inferential Aspect at Follow-up

Aspect	Pearson Chi-Square	Significance (p)	Effect Size (Cramer's V)
Inferential	17.69	.000	.45

According to Table 4.58, the proportions of participants' naïve, transitional and informed views of experimental group regarding inferential aspect of NOS was significantly different than comparison group at follow-up, χ^2 (2, n = 88) = 17.69, p < .0005. The magnitude of this difference was medium, Cramer's V = .45.

Separate chi-square tests were performed to find out the sources of the difference. Preliminary analysis indicated that the minimum expected frequencies were 18.64, 10.45, and 8.18for naïve, transitional, and informed levels respectively. This indicated that there was no violation of the assumption of chi-square test.

Table 4.70 Chi-square Test Results of Levels for Inferential Aspect of NOS at Follow-up

	Yates' Continuity Correction	Significance (p)	Effect Size (Phi Coefficient)
Naïve	15.38	.000	-.44
Transitional	8.42	.004	.34
Informed	2.03	.155	.18

As seen in Table 4.59, at follow-up measurement, there was significant differences in proportion of participants expressing naïve views, χ^2 (1, n = 88) = 15.38, p < .0005; and transitional views, χ^2 (1, n = 88) = 8.42, p = .004. However, there was no significant difference in the proportions of participants in experimental and comparison groups who had informed views, χ^2 (1, n = 88) = 2.03, p = .155, phi = .18. The result showed that comparison group participants more likely expressed naïve views (78%) while experimental group participants expressed more transitional inferential views (40%) at follow-up.

To sum up, when the between group difference were examined, it was found that there was not a statistically significant difference between the groups prior to instructions on any targeted NOS aspects. In other words, both experimental and comparison group students hold similar conception of targeted aspects of NOS before the instructions. On the other hand, when the result for students' post-instruction views were considered, it was found that there was a statistically significant difference between experimental and comparison groups on some aspects (tentative, subjective, and inferential) while there was not a statistically significant difference between the groups on others (empirical and creative & imaginative). Also, follow-up measurement result showed that there was a significant difference between the groups only on some targeted aspects (subjective, creative & imaginative, and inferential). Therefore, to make the result more informative, participants' NOS conceptions were discussed within each group separately throughout the next parts.

4.2.2 Within Group Comparisons of Participants' NOS Views

Under this heading, participants' NOS conceptions were explained within each group separately. The following research question was investigate in this part:

"How do each group students' nature of science views of targeted aspects change from pre-instruction to post-instruction and from post-instruction to follow-up measurements?"

For this purpose, experimental and comparison group participants NOS views were presented across two consecutive times of testing (pre- to post-instruction; and post-instruction to follow-up) respectively. Both qualitative and quantitative results were given.

4.2.2.1 Within Group Comparisons: Tentative Aspect of NOS

Students' understanding of tentative NOS was evaluated especially with the third questionnaire item of VNOS-E which explicitly asks "*Scientists are always trying to learn more about our world. Do you think what scientists know will change in the future?*". When students' responses were further investigated, it was found that some of the students' responses to the first questionnaire item ("*What is science?*") also provided clues to their tentative views. Moreover, few students referred to this aspect while responding to the second and fourth questionnaire items which are "*What are some of the other subjects you are learning?* (2.a); *How is science different from these other subjects*? (2.b)" and "*How sure are scientists about the way dinosaurs looked? Why?*(4.b)", respectively.

4.2.2.1.1 Tentative NOS Views of Experimental Group: Pre to Post-Instruction

The following part addressed experimental group participants' tentative NOS views before and after HOS instruction. The percent of participants in each level, the result of statistical test, and example quotes exemplifying the change (or consistency) were provided in order.

Bar graph in Figure 4.18 illustrates the proportions of participants in each level before and after HOS instruction. It indicates that the proportion of participants holding naïve views decreased while the proportion of participants articulating transitional and informed views increased after HOS instruction. Before the instruction, 25 (52%) students elucidated naïve views, while after the instruction this number reduced to 14 (29%). However, 15 (31%) students articulated transitional views before the instruction, while 18 (38%) students elucidated transitional views after HOS instruction. In terms of informed views, there were 8 (17%) students prior to instruction. On the other hand, this number increased to 16 (33%) students after HOS instruction.

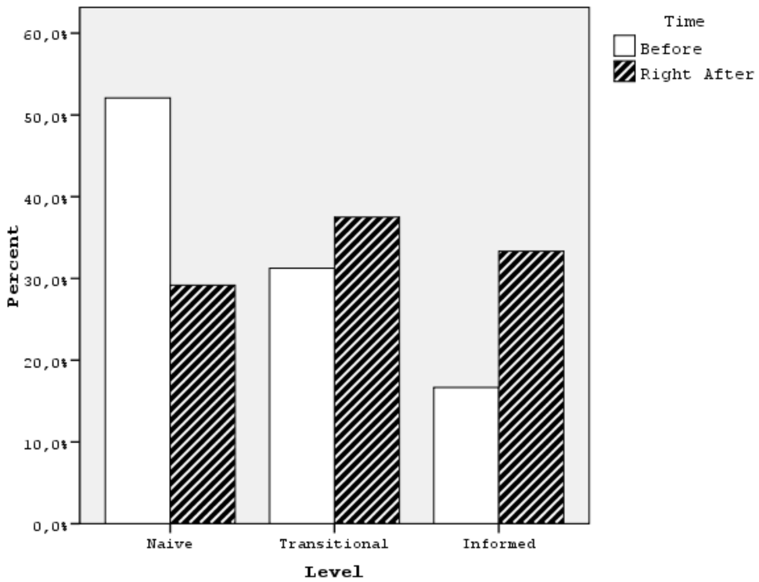

Figure 4.18 Experimental Group Participants' Pre and Post Tentative Views (%)

This change implied that HOS instruction may develop tentative views among students. This effect was tested using McNemar's test. To note, McNemar's test value was calculated by using the following formula as suggested by Fleiss, Levin, and Paik (2003).

Formula 2. McNemar's Test Value Computation for Repeated Pairs (Fleiss, et al., 2003):

$$\chi^2 = \frac{(|b - c| - 1)^2}{b + c}$$

Note: b and c refers to cells that represent changes from the first data collection to the second.

Table 4.60 summarizes the result of comparison of experimental group participants' tentative NOS views before and after HOS.

Table 4.71 McNemar Test Result of Experimental Group Participants' Pre and Post Tentative Views

Level	McNemar's Test*	Significance (p)
Naive	5.88	.013
Transitional	.16	.690
Informed	2.72	.096

*McNemar's Test Value has been calculated using Formula 2.

Table 4.60 indicates that the proportion of participants in experimental group who exhibited a naïve view about tentative aspect of NOS changed significantly right after HOS instruction, χ^2 = 5.88, p =.013. Participants were more likely expressed naïve views before HOS instruction (52%) than after HOS instruction (29%).

On the other hand, the proportion of participants in experimental group who hold transitional views about tentative aspect of NOS did not change significantly before and after HOS instruction, χ^2 = .16, p = .690.

Similarly, there was not a significant change in the proportion of participants who demonstrated an informed tentative views after HOS instruction when compared with proportion of participants before HOS instruction, $\chi^2 = 2.72$, $p = .096$.

The following quote pairs exemplify how participants' tentative views change before and after HOS instruction. It is appropriate to mention that students' responses were given as a table format to facilitate the reader to follow the presentation. First column illustrates the time of measurement (pre, post, or follow-up). Second column indicates VNOS-E questionnaire item, and last column shows students' responses to the related VNOS-E item. Note that each student's identification number was given in the first row in a brackets next to the label "Student's Response".

Measurement	Item	Student's Response (E12)
Pretest	1	*Science is to come up with an invention. In science, scientists make various inventions in different areas...*
	3	*I don't think what scientists know will change in the future.*
Posttest	1	*Science is any attempt in which scientists try to find new and different knowledge about a topic... I believe that scientists conduct study in order to modify or change what they know at present.*
	3	*Yes, every scientific knowledge is subject to change.*

Before HOS instruction, participant 12 elucidated naïve views while s/he articulated informed views after the instruction regarding tentative aspect of NOS. Before the instruction s/he seemed to believe that scientists invent the things around us. S/he also explicitly underlined that scientific knowledge is not subject to change. But after HOS instruction, s/he could perceive that science has evolutionary characteristics, therefore s/he stated that every scientific knowledge is subject to change.

Participant 19 could also express more adequate understanding in terms of tentative NOS after HOS instruction.

Measurement	Item	Student's Response (E19)
Pretest	3	*I think that what scientists know will not change in future because scientists may know everything.*
Posttest	3	*In my opinion, the knowledge scientists have may change in future...*

Before the instruction, her/his (E19) response to the third questionnaire item exhibit a naïve view by explicitly noting that scientific knowledge does not change. But after the instruction her/his response to the same question revealed an informed view by explicitly underlining the tentative nature of scientific knowledge.

Participant 51 was another student who developed more adequate views after HOS instruction.

Measurement	Item	Student's Response (E51)
Pretest	3	*Scientists discover and publish what is not known before. From my point of view scientific knowledge doesn't change.*
Posttest	3	*Yes I do believe that what scientists know will change in the future. For example ancient scientists thought that heart controls the body. This is not known like this right now. Similarly other knowledge in science can change too.*

This student (E51) developed her/his naïve understanding to an informed understanding of tentative NOS after HOS instruction. Before HOS instruction s/he seemed to believe that scientific knowledge should be accepted as if it is 100%

true, because reality is there and scientists find them. But after HOS instruction her/his view was significantly changed. By giving example from the history of science s/he explicitly stated that scientific knowledge is subject to change.

4.2.2.1.2 Tentative NOS Views of Comparison Group: Pre to Post-Instruction

Comparison group participants' tentative NOS views were presented in this part based on their views before and after curriculum-oriented instruction. Bar graph in Figure 4.19 shows the proportion of participants holding naïve, transitional, and informed views before and after curriculum-oriented instruction.

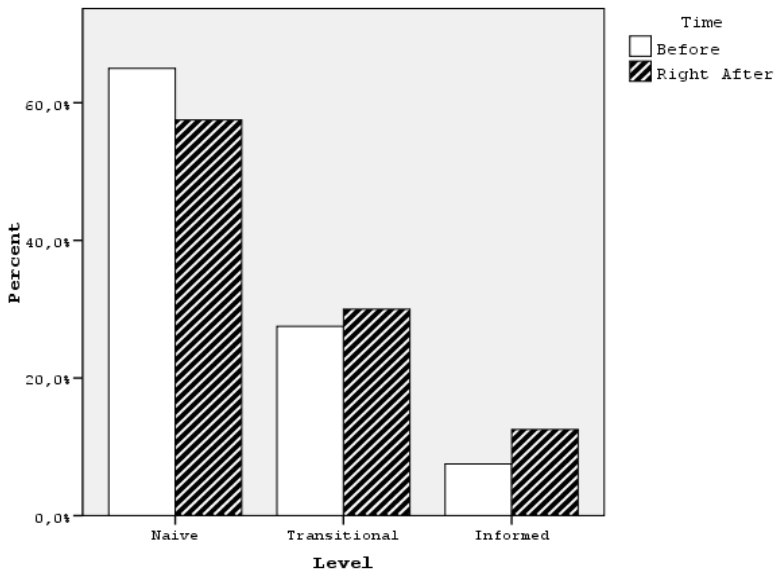

Figure 4.19 Comparison Group Participants' Pre and Post Tentative Views (%)

It was evident in the above bar graph that the number of participant elucidating naïve views declined while the number of participants in transitional and informed level increased slightly. There were 26 (65%) students holding naïve views before the curriculum-oriented instruction. This number reduced to 23 (58%) after the instruction. In contrast, there were 11 (28%) students articulated transitional views prior to the instruction while 12 (30%) students reflected the same views after the instruction. Similarly only 3 (8%) students elucidated informed views before curriculum-oriented instruction while 5 (13%) students demonstrated an informed views regarding tentative nature of science after the instruction.

The effect of curriculum-oriented instruction on students' tentative view was tested using McNemar's test. Table 4.61 shows the result of the comparison in each level.

Table 4.72 McNemar Test Result of Comparison Group Participants' Pre and Post Tentative Views

Level	McNemar's Test*	Significance (p)
Naive	.21	.648
Transitional	.00	1.000
Informed	.17	.687

*McNemar's Test Value has been calculated using Formula 2.

Table 4.61 reveals that the proportion of participants in comparison group who held naïve (χ^2 = .21, *p* = .648), transitional (χ^2 = .00, *p* = 1.000), and informed views (χ^2 = .17, *p* = .687) about tentative aspect of NOS did not change significantly from pre to post-instruction.

The following quote pairs show how the participants' view on tentative aspect was consistent from pre to post-instruction in comparison group. Participant 92, for example, elucidated transitional views before and after curriculum-oriented instruction.

Measurement	Item	Student's Response (C92)
Pretest	1	*There are always realities in science and scientific knowledge is proven by research and experiments...*
	3	*I think what scientists know may change in future... Scientists create models based on their own knowledge and try to explain phenomena using them. Their explanations may change when they observe the phenomena.*
Posttest	1	*Science covers everything, at least partly. By the help of scientific methods scientists can prove scientific knowledge and find the realities.*
	3	*What scientists know may change in future. For example Democritus asserted that atoms are same but other scientists found that different atoms have different properties.*

At the beginning of the study, when participant 92 was asked to define science, her/his response revealed a naïve conception where s/he stated that scientific knowledge is proven by scientific methods. At the same time s/he precisely expressed that what scientist know may change in future while responding to the third questionnaire item. Overall, her/his views were categorized as transitional at pretest. Likewise, after curriculum-oriented instruction, S/he stated that what scientists know is subject to change. On the other hand s/he expressed that scientists can prove scientific knowledge and can find the realities.

Participant 93 was another example showing that curriculum oriented instruction did not lead to any significant change on students views about tentative NOS. S/he articulated naïve tentative views before and after the instruction.

Measurement	Item	Student's Response (C93)
Pretest	3	*I think what scientists know will not change in the future because science has been proven by scientific experiments… For example, if you change the knowledge that the shape of the Earth is circular, nobody believes in anything and this result in chaos.*
Posttest	3	*No! What scientists know does not change in the future because scientists use experiments to prove it. For example the shape of the Earth was proved by satellite photos and if you start from one point and go forward, you will reach to the starting point. Those are the proof of the Earth's shape.*

Student 93 expressed relatively identical response at both measurements. It was evident in this participant's (C93) responses that s/he believes scientific knowledge to be certain and unchanging at both pre and post measurements. S/he also believes that scientific experiment makes all scientific knowledge verification possible. This participant also support her/his naïve views by providing example both before and after curriculum-oriented instruction.

4.2.2.1.3 Tentative NOS Views of Experimental Group: Post-Instruction to Follow-up

Under this heading, experimental group participants' post and follow-up tentative views were presented. Before reporting the result of the statistical test, the relative percent of students in each level right after the HOS instruction and at follow-up measurement were given (Figure 4.20).

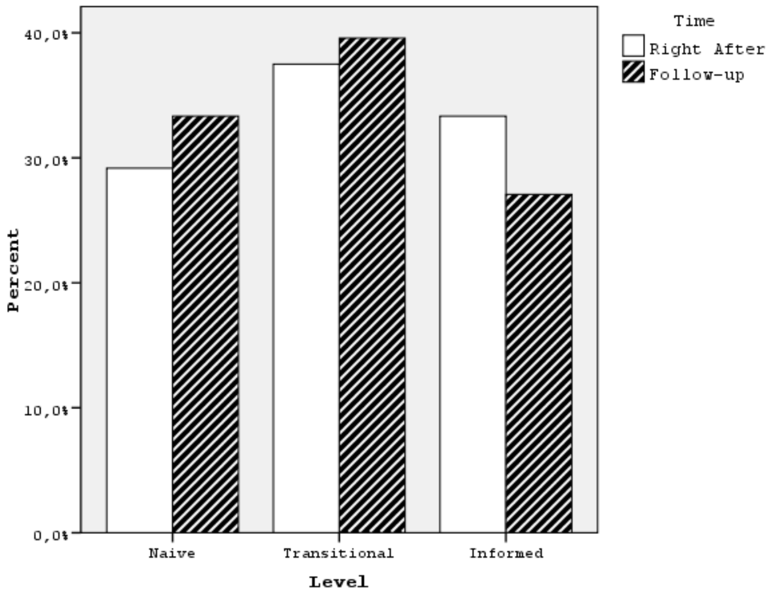

Figure 4.20 Experimental Group Participants' Post and Follow-up Tentative Views(%)

Figure 4.20 indicates that there was only a minor change in NOS views of students from post-instruction to follow-up measurement. There were 14 (29%) students holding naïve tentative views after the instruction while 16 (33%) students expressed naïve tentative views at follow-up. The number of participants having transitional views seemed to increase. Eighteen (38%) students articulated transitional views right after the instruction while 19 (40%) students expressed transitional views at follow-up. Conversely the proportion of participants having informed views seemed to decrease from post to follow-up regarding tentative aspect. There were 16 (33%) students at post measurement, and 13 (27%) students at follow-up measurement articulated informed views regarding tentative aspect of NOS.

The difference between experimental group participants' tentative views from post measurement to follow-up measurement was tested statistically using McNemar's test. Following table shows the result of this comparison.

Table 4.73 McNemar Test Result of Experimental Group Participants' Post and Follow-up Tentative Views

Level	McNemar's Test*	Significance (p)
Naive	.25	.625
Transitional	.00	1.000
Informed	1.33	.250

*McNemar's Test Value has been calculated using Formula 2.

Table 4.62 displays that the proportion of participants in experimental group who elucidated naïve (χ^2 = .25, p = .625), transitional (χ^2 = .00, p = 1.000), and informed views (χ^2 = 1.33, p = .250) about tentative aspect of NOS did not change significantly from post to follow-up measurement.

At five-week follow-up test experimental group participants follow-up views were similar to their post-instruction views. When students' responses investigated further, it was noticed that they articulated quite similar responses at both measurement. The quotes below exemplify the similarity in the views of participants at both measurements. To present a clear picture, quote pairs including students' post and follow-up responses were provided.

Measurement	Item	Student's Response (E18)
Posttest	1	*I think that science is any knowledge that is proven by scientists...*
	3	*I believe that scientific knowledge does not change. For example Edison invented light bulb and we still use it. In other words we still use the light bulbs and we will use it in future too.*
Follow-up	1	*To me, science is to investigate the truth; to find, and to learn the truth; and to be informed...*
	3	*I believe that scientific knowledge does not change. For example the researcher's knowledge about telephone does not change from past to present.*

Participant 18 did not seem to figure out tentative NOS at both post-instruction and follow-up measurements. At post-instruction s/he equated scientific knowledge with facts, and explicitly noted that it does not change. Similarly s/he seemed to equate scientific knowledge as accumulation of proven data at follow-up measurement, and stated that scientific knowledge is fixed and does not subject to change.

Following participant's responses at both measurements was also evident to the consistency of experimental group participants' understanding of tentative NOS.

Measurement	Item	Student's Response (E11)
Posttest	3	*I think that what scientists know may change in future because different scientists have different interpretations and this result in different conclusions...*
Follow-up	3	*I believe that people may change their ideas. By this way they may interpret the data in a different way. This is also possible for scientists. They [scientists] may reinterpret the data and their knowledge may change too...*

It was evident in participant 11's responses that s/he could demonstrate an informed understanding of tentative aspect of nature of science at both post and follow-up measurements. When s/he was asked the difference between science and other subject, s/he expressed that different scientists may have different position and this may allow them to explain events differently.

4.2.2.1.4 Tentative NOS Views of Comparison Group: Post-Instruction to Follow-up

In this part comparison group participants' views of tentative NOS were presented based on their post and follow-up views. The percent of students in each level right after the instruction and at follow-up measurement were given at Figure 4.21.

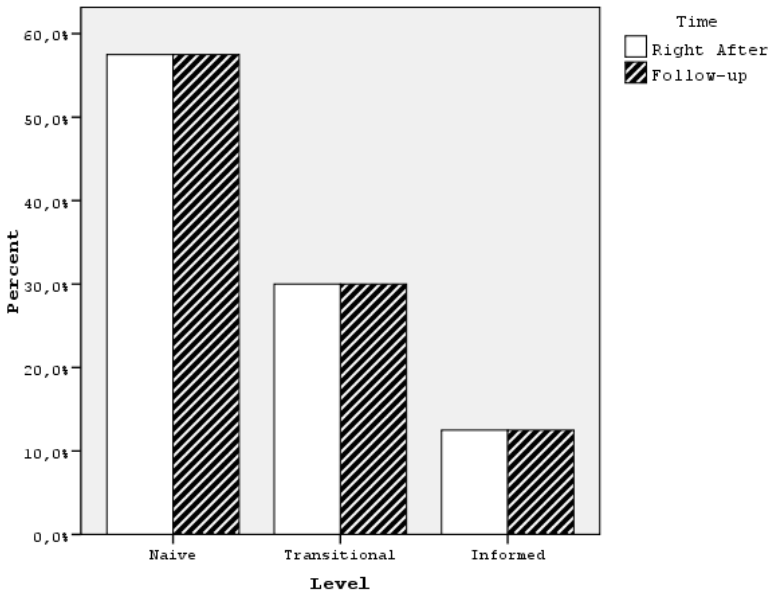

Figure 4.21 Comparison Group Participants’ Post and Follow-up Tentative Views (%)

The Figure 4.21 indicates that there was no change in comparison group students' tentative NOS views from post to follow-up measurement. There were 23 (58%) students holding naïve views after the curriculum-oriented instruction and at follow-up measurement. However, there were 12 (30%) students articulated transitional views while 5 (13%) students elucidated informed views at both measurements.

No difference was observed between post and follow-up tentative views among comparison group. Therefore the result of statistical analysis was not reported here. The following quote pairs also verified that students' views were quite parallel at post and follow-up measurements.

Measurement	Item	Student's Response (C70)
Posttest	3	*What scientists know is proven. I mean scientists can prove their knowledge; therefore, I think that what scientists know will not change in the future.*
Follow-up	3	*I don't think what scientists know will change in the future because they [scientists] prove that knowledge.*

This student (C70) articulated naïve tentative views at both measurements. S/he explicitly articulated that scientific knowledge is not subject to change after curriculum oriented instruction and at follow-up measurement. S/he seemed to perceive scientific knowledge as the accumulation of proven data and scientists' job as verification of realities in the nature. In other words s/he could not comprehend the tentative NOS both post and follow-up measurements.

Student 76 was another example showing that comparison group students elucidated quite similar responses at post and follow-up measurement. This student expressed informed views after curriculum oriented instruction and at five-week follow-up measurement.

Measurement	Item	Student's Response (C76)
Posttest	1	*Science is a discipline in which there is not a single reality...*
	3	*I consider that scientific knowledge may change. For example, in the past it was thought that atoms cannot be divided. But today we know that it can be...*
Follow-up	3	*I think that what scientists know may change in the future. Because, when Galileo said that the Earth is spherical nobody paid attention to him. But now, people believe it. This is an example for how scientists' knowledge may change.*

Student 76 could demonstrate an informed understanding of tentative nature of science by explicitly underlying that scientific knowledge is subject to change. S/he supplied an example at both post and follow-up measurement to the tentative aspect of NOS. This student was a good example showing the consistent trends in student's tentative views about scientific knowledge from post instruction to follow-up views.

4.2.2.2 Within Group Comparisons: Subjective Aspect of NOS

The conception of students subjective NOS was assessed mostly with the fifth VNOS-E questionnaire item which exactly ask "*A long time ago all the dinosaurs died. Scientists have different ideas about why and how they died. If scientists all have the same facts about dinosaurs, then why do you think they disagree about this?*". Moreover some of the students' responses to fourth questionnaire item that is "*How do scientists know that dinosaurs once lived on the earth?* (4.a)" also provided evidence to evaluate students' subjective views. In addition, a few students' responses to sixth item; ("*TV weather people show pictures of how they think the weather will be for the next day. They use lots of scientific facts to help* *them make these pictures. How sure do you think the weather people are about these pictures? Why?*"; first, second and third items (see section 4.2.2.1 for these questionnaire items) also referred to this aspect.

4.2.2.2.1 Subjective NOS Views of Experimental Group: Pre to Post-Instruction

Before presenting the difference in the proportion of participants who held naïve, transitional and informed views regarding subjective aspect before and after HOS instruction, it is useful to illustrate the percent of participants in each level (Figure 4.22).

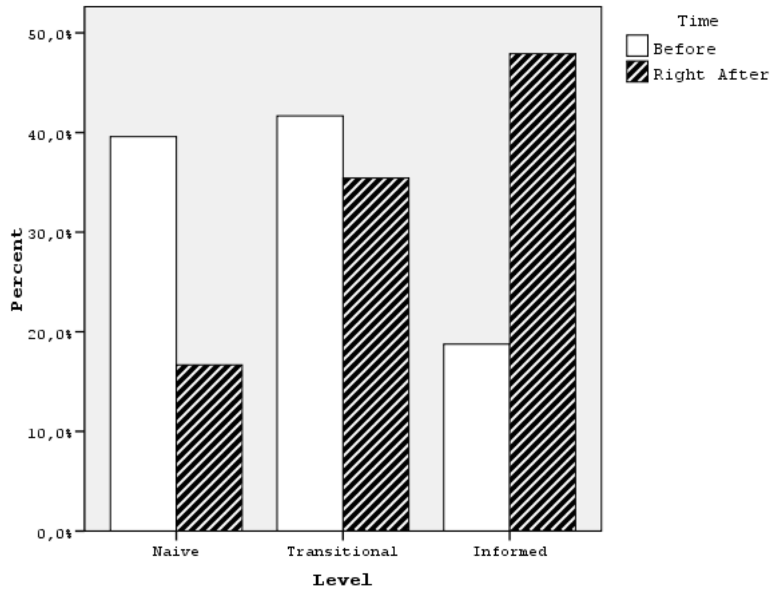

Figure 4.22 Experimental Group Participants' Pre and Post Subjective Views (%)

The bar graph in Figure 4.22 clearly indicates that the proportion of participants holding naïve views decreased almost by half, while the proportion of participants articulating informed views increased by more than twice after the HOS instruction. Before instruction, 19 (40%) students held naïve views while 8 (17%) students expressed naïve views after HOS instruction. Similarly, 20 (42%) students articulated transitional views before instruction, while 17 (35%) students elucidated transitional views after HOS instruction. In terms of informed views, 9 (19%) students expressed informed views prior to instruction. On the other hand, 23 (48%) students articulated informed views after HOS instruction. This result implied that HOS instruction has merits to develop students conception of subjective NOS. This effect was tested using McNemar's test. Following table shows the result of the comparison before and after HOS instruction in each level.

Table 4.74 McNemar Test Result of Experimental Group Participants' Pre and Post Subjective Views

Level	McNemar's Test*	Significance (p)
Naive	5.26	.019
Transitional	.17	.678
Informed	7.68	.004

*McNemar's Test Value has been calculated using Formula 2.

Table 4.63 indicates that the proportion of participants in experimental group who held naïve views about subjective aspect of NOS changed significantly right after HOS instruction, $\chi^2 = 5.26$, $p = .019$. Participants were more likely in naive level before HOS instruction (40%) than after HOS instruction (17%).

The proportion of participants in experimental group who reflected her/his transitional views about subjective aspect of NOS did not change significantly before and after HOS instruction, $\chi^2 = .17$, $p = .678$.

There was a significant change in the proportion of participants who demonstrated an informed subjective views after HOS instruction when compared with proportion of participants before HOS instruction, $\chi^2 = 7.68$, $p = .004$. Participants were more likely in informed level after HOS instruction (48%) than before HOS instruction (19%).

The following quotes pair illustrates how experimental group participants' views about subjective aspect of NOS changed after HOS instruction.

Measurement	Item	Student's Response (E33)
Pretest	5	*The trace and the fossil of each dinosaur are different from each other. Therefore the fossils they [scientists] are working on belong to different dinosaurs. So they disagree about them [dinosaurs' extinction].*
Posttest	5	*Each scientist has different point of view. They are interpreting the evidence based on it. That is why they don't agree with each other about the reason why dinosaurs disappeared.*

Participant 33 articulated naïve views before HOS instruction while s/he articulated informed views after the instruction. Before HOS instruction, s/he believed that scientists worked on different fossils and different dinosaurs may be died from different reasons. By posing it, s/he seemed to believe that if scientists observed the same dinosaurs' traces, they would draw the same conclusion. S/he seemed science as bias free before the instruction. But just after the instruction, s/he demonstrated an understanding that scientists interpret the evidence based on their own point of view inevitably. That is why they disagree about dinosaurs' extinction.

Participant 40 was another example showing that students who were in experimental group exhibited more informed views regarding subjective aspect of NOS after HOS instruction.

Measurement	Item	Student's Response (E40)
Pretest	5	*I think that the fossils different scientists examine found in different part of the Earth and different disasters might take place in different part of the Earth. So all scientists study on different fossils. That is why they disagree about dinosaurs' extinction.*
Posttest	5	*All scientists have different ideas. Therefore they have different position on this topic [why dinosaurs disappeared].*

Regarding subjective aspect, participant 40 also exhibited more informed views after HOS instruction. S/he elucidated naïve views before the instruction. S/he hesitated to accept that scientists had disagreement about a scientific claim. But after the instruction s/he could demonstrate an approval that scientists may have different position because their background is different.

4.2.2.2.2 Subjective NOS Views of Comparison Group: Pre to Post-Instruction

In this part, comparison group participants' subjective NOS views were explained by considering their views before and after curriculum-oriented instruction. Before evaluating the result of statistical test, the relative percent of students in each level were displayed (Figure 4.23).

As seen in Figure 4.23, there were 22 (55%) students who did not perceive subjective NOS and articulated naïve views before curriculum-oriented instruction. This number reduced to 19 (48%) after the instruction. The number of participants in transitional level did not change before and after curriculum-oriented instruction (13 students in both measurements). There was a slight increase in the number of students who demonstrated an informed understanding as well. Five (13%) students elucidated informed views before curriculum-oriented instruction while 8 (20%) students held informed views after the instruction.

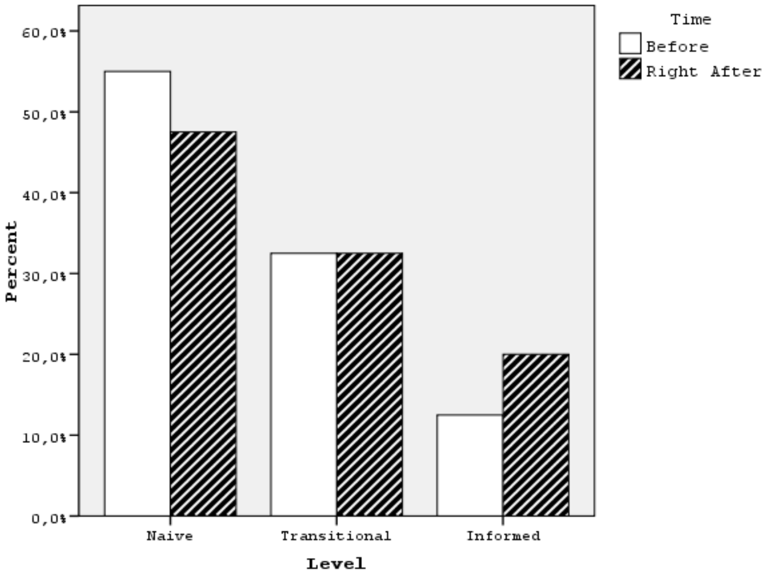

Figure 4.23 Comparison Group Participants' Pre and Post Subjective Views (%)

The effect of curriculum-oriented instruction on students' subjective view was tested using McNemar's test. Table 4.64 shows the result of the comparison in each level.

Table 4.75 McNemar Test Result of Comparison Group Participants' Pre and Post Subjective Views

Level	McNemar's Test*	Significance (p)
Naive	.21	.648
Transitional	.00	1.000
Informed	.36	.549

*McNemar's Test Value has been calculated using Formula 2.

Table 4.64 reveals that the proportion of participants in comparison group who held naïve (χ^2 = .21, p = .648), transitional (χ^2 = .00, p = 1.000), and informed views (χ^2 = .36, p = .549) about subjective aspect of NOS did not change significantly from pre to post-instruction.

Following quotes pairs exemplify representative responses of students in comparison group regarding subjective aspect of NOS at pre and post measurements. It was evident in their responses that their view about subjectivity in scientific endeavor was durable. In other words curriculum-oriented instruction did not lead participants' subjective NOS views to develop.

Measurement	Item	Student's Response (C66)
Pretest	4.a	*Dinosaurs are appearing on TV, so scientists could gather information about them from TVs. They [scientists] might collect information from computers too. Therefore they [scientists] know that dinosaurs lived on the Earth...*
	6	*Weather people are sure about weather pictures because they [weather people] obtain that information from scientists.*
Posttest	4.a	*Scientists collect information about dinosaurs from TVs, other people, and computers. Therefore they [scientists] know that dinosaurs' survived in ancient times...*
	6	*Weather people are 100% sure about weather picture because they broadcast the report of experts and scientists.*

This student (C66) expressed naïve subjective views before and after curriculum-oriented instruction. Her/his response could refer that scientists' individual views do not manipulate their views and what scientists say is true and should be believed. Therefore it was evident in her/his response that s/he could not demonstrate an understanding that factors other than data could allow scientists to support scientific argumentations.

Likewise it was apparent in the following student's response that comparison group students expressed similar views before and after the instruction.

Measurement	Item	Student's Response (C87)
Pretest	2	*Science is different from other school subjects. Others, such as music and art, require talents. But science is distant from subjective component. It requires specialist knowledge...*
	5	*In the times of dinosaurs there were different conditions therefore scientists don't know what happened exactly. They are explaining what seems more rational to them. Therefore they disagree about their [dinosaurs'] extinction.*
Posttest	1	*Science is facts. Science is to get away from ignorance and to observe the facts with the most realistic ways...*
	5	*Scientists disagree about the way dinosaurs disappeared, because those fossils are predating to millions of years. Therefore they draw conclusion based on their own interpretations.*

Student 87 articulated transitional views about subjective NOS at both measurements. Before the instruction, when s/he was asked the difference between science and other subjects, s/he explicitly stated that science is free from subjective elements but at the same time s/he could reflect her/his informed understanding in the case of dinosaurs' extinction. Therefore s/he held a transitional understanding of subjective NOS before the instruction. Similarly s/he could figure out the influence of personal characteristics on scientists' conclusions while referring to dinosaurs' disappearance. However, s/he could not extend her/his informed subjective views to define science after the instruction. In other words s/he could not develop her/his transitional understanding to informed level after curriculum-oriented instruction.

4.2.2.2.3 Subjective NOS Views of Experimental Group: Post-Instruction to Follow-up

Under this subtitle, experimental group participants post and follow-up subjective views were presented. Before reporting the result of statistical test, the relative percent of students in each level right after the HOS instruction and at follow-up measurement were given at Figure 4.24.

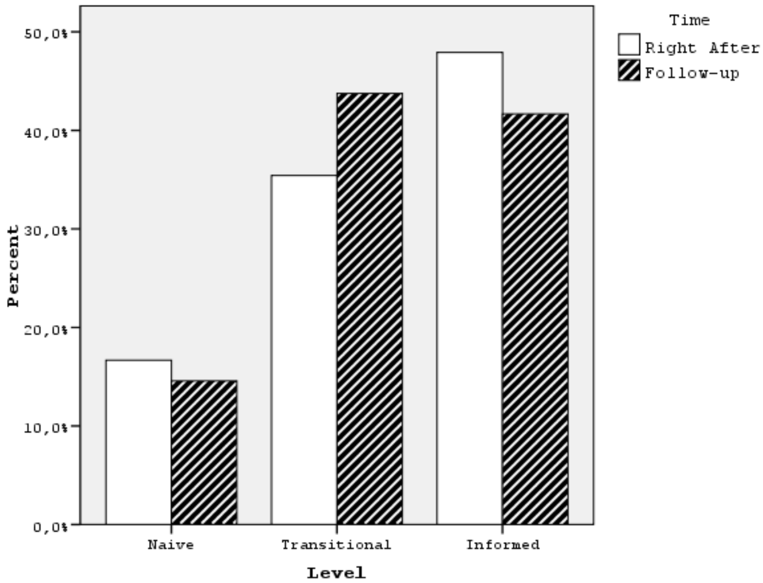

Figure 4.24 Experimental Group Participants' Post and Follow-up Subjective Views (%)

Figure 4.24 indicates that there was just a minor change in experimental group students' subjective NOS views from post-instruction to follow-up measurement. There were 8 (17%) students holding naïve views after the instruction while 7 (15%) students expressed naïve views at follow-up. The number of participants having transitional views seemed to increase. Seventeen (35%) students articulated transitional views right after the instruction while 21 (44%) students expressed transitional views at follow-up. Conversely the proportion of participants having informed views seemed to decrease. There were 23 (48%) students at post measurement, and 20 (42%) students at follow-up measurement holding informed views.

The difference between experimental group participants' subjective views from post measurement to follow-up measurement was tested statistically using McNemar's test. Following table shows the result of the test.

Table 4.76 McNemar Test Result of Experimental Group Participants' Post and Follow-up Subjective Views

Level	McNemar's Test*	Significance (p)
Naive	.00	1.000
Transitional	2.25	.125
Informed	1.33	.250

*McNemar's Test Value has been calculated using Formula 2.

Table 4.65 displays that the proportion of participants in experimental group who held naïve (χ^2 = .00, p = 1.000), transitional (χ^2 = 2.25, p = .125), and informed views (χ^2 = 1.33, p = .250) about subjective aspect of NOS did not change significantly from post to follow-up measurement.

In addition to the quantitative comparison, students' responses to subjective NOS were also examined qualitatively. The finding revealed that experimental group students elucidated similar understandings both at posttest and follow-up test. The quotes below exemplify the similarity in the views of participants from posttest to follow-up measurement.

Measurement	Item	Student's Response (E39)
Posttest	1	*Science can be proven by experiments. In science everything has been connected to a reality and nobody assert the contrary...*
	5	*Scientists disagree about dinosaurs' extinction because they are adding their own interpretation into that knowledge.*
Follow-up	2	*Scientists discover the things around the world by the help of experiments. Science is different from others because it doesn't change person to person, I mean you like or dislike music but science affects everybody in the same way...*
	5	*Scientists all have the same facts about dinosaurs but they disagree about it [dinosaurs' extinction] because they all possess different ideas.*

Student 39 elucidated transitional views regarding subjective aspect of NOS at both measurements. In her/his post and follow-up response, s/he could demonstrate an understanding that scientists could make different inference based on their own interpretation of the same data (subjective). But at the same time s/he stated that science does not change one person to another (objective). Therefore her/his collectivist response indicated her/his transitional subjective view.

It was also evident in the next participants’ responses that experimental group students' articulated similar subjective views from post to follow-up measurement.

Measurement	Item	Student's Response (E35)
Posttest	5	*I think that the reason why they [scientists] disagree [about dinosaurs' extinction] is that they [scientists] all have different thoughts. Also every scientist may look this situation from different directions.*
Follow-up	5	*... Because every scientist has different thoughts, they have different views about this situation [the way dinosaurs' disappeared].*

Student 35 could recognized that scientists' background knowledge and their views can affect what they conclude at both measurements. In other words s/he could express an adequate views regarding subjective aspect of NOS at both measurements.

4.2.2.2.4 Subjective NOS Views of Comparison Group: Post-Instruction to Follow-up

As similar to the previous part, following part describes comparison group students' understanding of subjective NOS at post and follow-up measurements. The percent of students in each level were given at Figure 4.25.

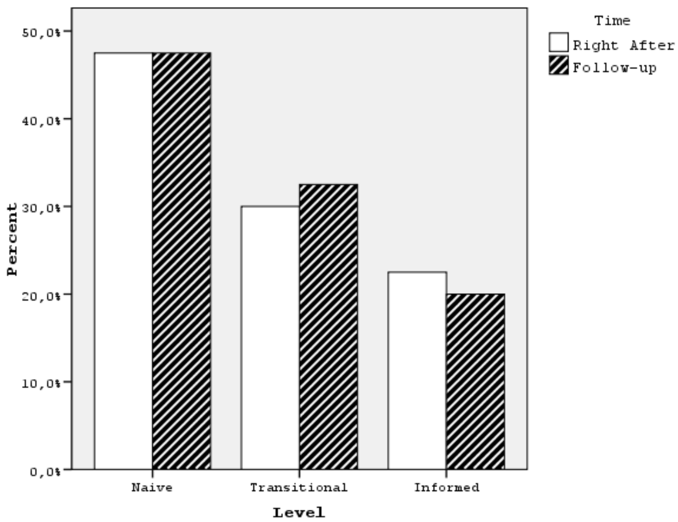

Figure 4.25 Comparison Group Participants' Post and Follow-up Subjective Views (%)

The bar graph above indicates that there was almost no change in NOS views of students regarding subjective aspect of NOS. Actually, there were 19 (48%) students holding naïve views both at post-instruction and follow-up measurements. Similarly, there were 13 (33%) students articulated transitional views after the instruction and 12 (30%) students at follow-up. In turn, 8 (20%) students elucidated informed views after curriculum-oriented instruction and 9 (23%) students at follow-up measurement.

The effect of curriculum-oriented instruction on students' subjective view was tested using McNemar's test. Table 4.66 shows the result of the comparison for in each level.

Table 4.77 McNemar Test Result of Comparison Group Participants' Post to Follow-up Subjective Views

Level	McNemar's Test*	Significance (p)
Naive	.00	1.000
Transitional	.00	1.000
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.66 reveals that the proportion of participants in comparison group who held naïve, transitional, and informed views about subjective aspect of NOS did not change significantly from post to follow-up measurement ($\chi^2 = .00$, $p = 1.000$).

In addition to the statistical comparison which showed that comparison group students held similar subjective views at both assessments, qualitative comparison also supported that they articulated quite similar responses from post to follow-up.

Measurement	Item	Student's Response (C83)
Posttest	5	*Scientists might have investigated it with different scientific methods, if they used the same method they would agree about it [dinosaurs' extinction]... In my point of view we require more research to know exactly why they [dinosaurs] disappeared.*
Follow-up	5	*All of them [scientists] might conduct different experiments and different research. Therefore they disagree about it [how dinosaurs extinct]. In order to prove why they extinct surely, more experiments and more research are needed.*

This students (C83) could not comprehend subjective NOS at both measurement and elucidated naïve views. S/he referred that when the scientists use the same scientific method or scientific experiments, they will reach the same conclusion. S/he could not demonstrate an understanding that different scientists can deduce different conclusion from the same datasets even they use the same scientific methods or experiments. S/he also stated that if scientists conduct enough experiment and research they will know how dinosaurs' extinct.

Following students elucidated informed views at both post and follow-up measurements which demonstrate the consistency of comparison groupstudents' responses from post to follow-up measurement.

Measurement	Item	Student's Response (C82)
Posttest	1	*Science is a discipline in which there is not a definite answer and it may change person to person...*
	5	*It is not unusual that scientists propose different explanation to dinosaur's extinction. As I said before scientific knowledge is relative. Therefore scientists may draw different conclusions from the same data.*
Follow-up	5	*I think that scientists interpret the data about dinosaurs extinction based on their own interpretation. That is why they draw different conclusions.*

Students 82 in comparison group could seem to comprehend an informed understanding of subjective NOS at both post and follow-up measurements. While responding to the first and fifth questionnaire item, s/he could refer that science is relative and may change person to person, therefore scientists may reach different conclusion looking at the same data especially in the case of dinosaurs' extinction. To sum, her/his response exhibited an informed view of subjective nature of science.

4.2.2.3 Within Group Comparisons: Empirical Aspect of NOS

Students' empirical views were primarily explicated in response to 1st, 2nd, and 4th questionnaire items in VNOS-E (see section 4.2.2.1 for these items). Moreover some students' responses to fifth and sixth items also provided evidence to evaluate students' empirical NOS views (see section 4.2.2.2 for these items).

4.2.2.3.1 Empirical NOS Views of Experimental Group: Pre to Post-Instruction

In this part, experimental group participants' NOS views were addressed based on their pre- and post-instruction views.

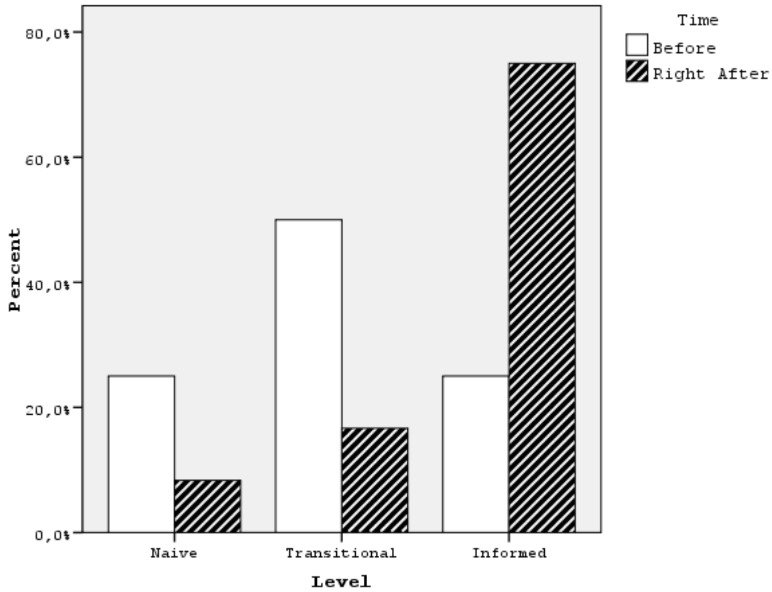

Figure 4.26 Experimental Group Participants' Pre and Post Empirical Views (%)

Bar graph in Figure 4.26 clearly indicates that the number of participants exhibiting naïve and transitional views decreased after the HOS instruction while the number of participants in informed level increased substantially. Before the instruction 12 (25%) students elucidated naïve views, while only 4 (8%) students expressed naïve views after HOS instruction. Similarly, 24 (50%) students articulated transitional views before instruction, while 8 (17%) students elucidated transitional views after HOS instruction. In terms of informed views, 12 (25%) students demonstrated an informed view prior to the instruction. On the other hand, 36 (75%) students demonstrated informed views after HOS instruction. This result implied that HOS instruction had positive effect on fostering informed views among students. Statistical significance of this effect was tested using McNemar's test and the results were tabulated below (Table 4.67).

Table 4.78 McMemar Test Result of Experimental Group Participants' Pre and Post Empirical Views

Level	McNemar's Test*	Significance (p)
Naive	3.06	.077
Transitional	9.38	.002
Informed	16.53	.000

*McNemar's Test Value has been calculated using Formula 2.

It is seen in Table 4.67 that the proportion of participants in experimental group whose response reflected a naïve views about empirical aspect of NOS did not change significantly right after HOS instruction compared to prior to instruction, $\chi^2 = 3.06$, $p = .077$.

However, the proportion of participants whose response revealed a transitional view of empirical aspect of NOS changed significantly before and after HOS instruction, $\chi^2 = 9.38$, $p = .002$. Participants more likely exhibited a transitional views of empirical NOS before HOS instruction (50%) than after HOS instruction (17%).

There was also a significant change in the proportion of participants who elucidated informed views, $\chi^2 = 16.53$, $p < .0005$. Participants were more prone to appreciate the role of empirical evidence in science after HOS instruction (75%) than before HOS instruction (25%).

Actually, at the outset of the treatment there were totally 12 students in experimental group having informed view on empirical aspect of NOS while this number increased to 36 at following to HOS instruction. In other words three times more participants held informed views after the HOS instruction regarding empirical aspect of NOS. The following quotes show how the participants' views on empirical aspect changed from pre to post-instruction in experimental group. Also in this part the quote pairs for each participant were introduced to make the change comprehensible.

Measurement	Item	Student's Response (E6)
Pretest	1	*Science is arising from mental thoughts of a person...*
	2	*Science is different from other subjects because science is the accumulations of those thoughts. There are also some thoughts in other subject but they are limited.*
Posttest	2	*Scientists always reasons about situations. In science people do research, observe the nature, and conduct experiment on scientific topics. This is the difference between science and other topics.*

Participant 6 expressed naïve views before HOS instruction while s/he articulated informed views after the instruction. S/he could not make a distinction between science and other disciplines in terms empirical based nature of science before the instruction. Although s/he expressed science is different from other subjects, s/he failed to relate this to empirical nature of science and stressed that science is based on personal thoughts. After HOS instruction, however, s/he could acknowledge that science is different from other disciplines due to its empirical nature and s/he referred to the observation, research, and experiments in science.

Participant 3 also elucidated naïve and informed views before and after the instruction respectively.

Measurement	Item	Student's Response (E3)
Pretest	1	*Science takes place in mysterious laboratories. Scientists go and develop strange ideas there. This, of course, takes a long time. But ultimately they discover new scientific knowledge.*
Posttest	1	*I think that science is an effort to seek for evidence in nature. For example people once believed that the Earth was flat, but Galileo find evidence to support the idea that the Earth is in spherical like shape…*
	2	*Science is completely different than other school subjects because drawing, for example, is an art but science always tries to investigate and search the things...*

Before HOS instruction, when s/he (E3) was asked the definition of science, her/his response reflected a naïve view where s/he viewed science as a discipline in which scientists discover strange and unknown things in closed laboratories. However after the instruction s/he was able to refer science as an attempt to study nature by collecting evidence while defining science. S/he also separate science from other subjects in a way that science investigates the things unlike the others.

The next quote pair illustrates one of the students who developed her/his naïve understanding to transitional about empirical NOS after HOS instruction.

Measurement	Item	Student's Response (E38)
Pretest	2	*Science is not different than other school subjects. As others it is just a school subject…*
	4.a	*Dinosaurs were damaging people, so they [people] killed them [dinosaurs]. They [scientists]saw dinosaurs' body and become sure that they [dinosaurs] had existed once.*
Posttest	2	*Science is not different than other school subjects. The only difference is that science contains experiments…*
	4.a	*Dinosaurs were killed by ancient people and they [scientists] examined and studied on them [dinosaurs' remaining]. By this way scientists know that they [dinosaurs] once lived on the Earth.*

The participant 38 could not recognize the difference between science and other disciplines before HOS instruction. S/he made no distinction between science and other school subjects as describing science. In the case of dinosaurs, s/he also stated that scientists saw the dinosaurs and become sure about their existence before the instruction. In other words, s/he seemed to have an idea that "seeing is believing" before the instruction. After the instruction, although s/he could not explicitly distinguish it from other school subjects, s/he was able to state that experimentation is a part of science. S/he also developed her/his understanding in the case of dinosaurs. S/he expressed that scientists examined dinosaurs to find indication about them. Therefore s/he developed her/his naïve view to transitional after HOS instruction.

4.2.2.3.2 Empirical NOS Views of Comparison Group: Pre to Post-Instruction

In this part, comparison group students' empirical NOS views were presented by comparing their pre- and post-instruction views. With the purpose of maintaining the flow of presentation, the percent of participants in each level before and after the instruction, the result of statistical test, and example quotes exemplifying the their views were given respectively.

Before presenting the statistical test result of comparison in the proportion of participants who held naïve, transitional or informed views regarding empirical aspect, the percent of participants in each level were shown (Figure 4.27).

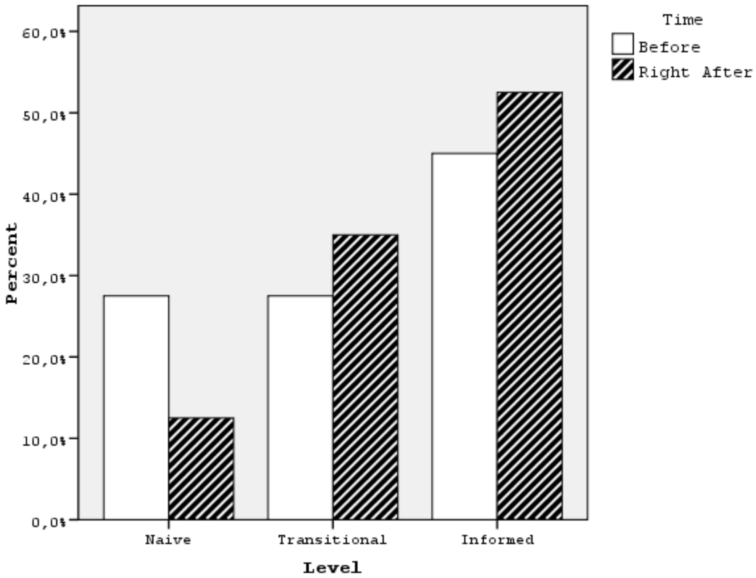

Figure 4.27 Comparison Group Participants' Pre and Post Empirical Views (%)

Bar graph in Figure 4.27 shows that the proportion of participants whose response revealed a naïve understanding decreased after the curriculum-oriented instruction. There were 11 (28%) students who exhibit naïve views of empirical NOS before the curriculum-oriented instruction. This number reduced to 5 (13%) after the instruction. The number of participants in transitional level and informed level increased slightly. There were 11 (28%) students who articulated transitional views prior to the instruction while 14 (35%) students exhibit the same views after the instruction. Similarly 18 (45%) students elucidated informed views before curriculum-oriented instruction while 21 (53%) students elucidated informed views regarding empirical nature of science after the instruction. This result implied that curriculum-oriented instruction may also have some positive effect on fostering students' empirical views of NOS.

The effect of curriculum-oriented instruction on students' empirical view was tested using McNemar's test. Table 4.68 shows the result of the comparison before and after curriculum-oriented instruction in each level.

Table 4.79 McNemar Test Result of Comparison Group Participants' Pre and Post Empirical Views

Level	McNemar's Test*	Significance (p)
Naive	2.50	.109
Transitional	.31	.581
Informed	.36	.549

*McNemar's Test Value has been calculated using Formula 2.

As seen in Table 4.68 there was not a significant change in the proportion of participants who demonstrated naïve views of empirical NOS after curriculum-oriented instruction when compared with the proportion of participants before the instruction, $\chi^2 = 2.50$, $p = .109$.

Similarly, the proportions of participants in comparison group who demonstrated a transitional views about empirical aspect of NOS did not change significantly before and after curriculum-oriented instruction, $\chi^2 = .31$, $p = .581$.

Consistently, there was not a significant change in the proportion of participants who expressed informed views after curriculum-oriented instruction when compared with proportion of participants before curriculum-oriented instruction, $\chi^2 = .36$, $p = .549$.

The following quote pairs show how the participants' view on empirical aspect was consistent from pre to post-instruction in comparison group. Participant 62 expressed naïve views before and after curriculum-oriented instruction.

Measurement	Item	Student's Response (C62)
Pretest	2	*I don't think that science is different than other school courses; they are all same... Science seems to me as a subdivision of art. Because some people are skillful and others not in science as in the art.*
Posttest	1	*Science is one of the school subjects that we have to take in school...*
	2	*Science is not different than other subjects, as I mentioned before, it is just a course...*

This student (C62) could not make a distinction between science and other disciplines in terms of empirical based nature of science. Her/his response revealed a naïve view where s/he believed science just a course that s/he is supposed to take in school. In her/his pre and post response s/he equated science with other school subjects.

Similarly, participant 77 also indicated naïve empirical views before and after curriculum-oriented instruction.

Measurement	Item	Student's Response (C77)
Pretest	2	*Science is one of our courses in the school. Others, for example literature and art, are also courses in the school. I mean no difference exist between science and others.*
Posttest	2	*There is nothing that makes science different than other school courses. They are all one of the school subjects and they are all identical…*
	4.b	*Scientists found the bones of dinosaurs and combine them. The appearance of dinosaurs emerged spontaneously.*

This students failed to understand the empirical nature of science before and after the instruction. In her/his response to the second questionnaire item about the distinction between science and other subjects, s/he could not differentiate science from other disciplines by taking into account the empirical nature of science. S/he considered science as a school subject. It was also apparent in her/his response to the fourth questionnaire item at post-measurement that s/he believed science as a jigsaw activity in which scientists interlock the parts together and produces a complete picture of the phenomena. In other words s/he seemed to believe that scientists do not need to draw conclusions based on the evidence at hand. Taken as a whole, this students' pre and post-instruction responses could not refer to developed understanding of the crucial role of evidence in science.

The next quote pairs illustrate another participant in comparison group who exhibit a transitional empirical view before and after the instruction.

Measurement	Item	Student's Response (C90)
Pretest	2	*Science is like other school subjects. But sometimes we go laboratories and conduct experiments in our science classes. There are not experiments in others.*
Posttest	2	*Science is different from other school subjects in a way that we cannot conduct experiment in others but we do in science. Actually I believe that science encompass all other school subject.*

Before the instruction, this participant (C90) stated that science is similar to other courses except it includes conducting experiments. In her/his post-instruction understanding, s/he could differentiate science from other disciplines, but s/he viewed science as an overarching discipline covering all other school subjects.

Overall, this student pre- and post instruction responses reflected that s/he could refer to the experimentation in science, but s/he could not make reference to the role of observation.

4.2.2.3.3 Empirical NOS Views of Experimental Group: Post-Instruction to Follow-up

Similar to the previous parts, the following part addressed the comparative understanding of experimental group students' post and follow-up empirical views. Before giving the result of statistical significance of the difference between experimental group students' post and follow-up empirical views, the relative percent of students in each level right after the HOS instruction and at follow-up measurement were shown at Figure 4.28. As clearly shown, there was a slight change in NOS views of students regarding empirical aspect of NOS from post-instruction to follow-up measurement. No change was evident in the proportion of naïve views from post-instruction to follow-up measurement. There were 4 (8%) students in post and follow-up measurement holding naïve empirical views. The number of participants elucidating transitional views seemed to increase. In fact, 8 (17%) students articulated transitional views right after the instruction while 11 (23%) students expressed transitional views at follow-up. Conversely the proportion of participants having informed views seemed to decrease. There were 36 (75%) students at post measurement, and 33 (69%) students at follow-up measurement holding informed views.

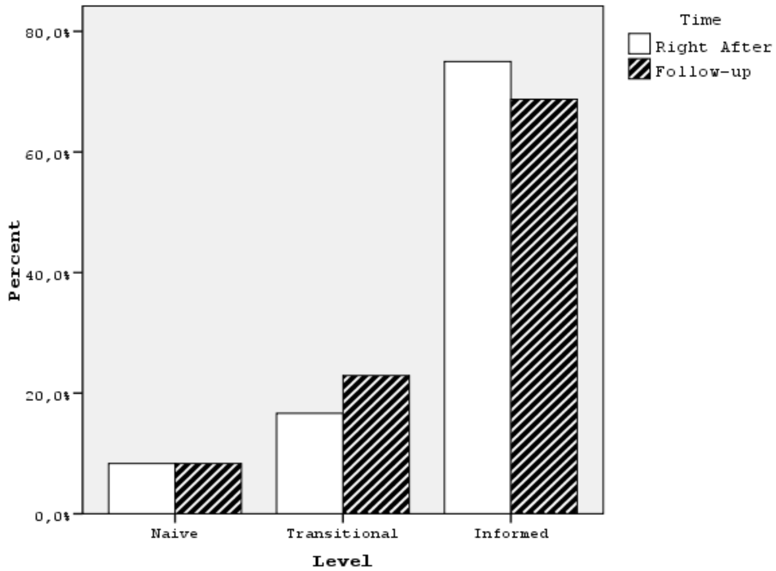

Figure 4.28 Experimental Group Participants' Post and Follow-up Empirical Views (%)

As stated earlier, the difference between experimental group participants' empirical views from post measurement to follow-up measurement was evaluated statistically using McNemar's test. Following table shows the result of this comparison.

Table 4.80 McNemar Test Result of Experimental Group Participants' Post and Follow-up Empirical Views

Level	McNemar's Test*	Significance (p)
Naive	0.00	1.00
Transitional	1.33	.250
Informed	1.33	.250

*McNemar's Test Value has been calculated using Formula 2.

It is seen in Table 4.69 that the proportion of participants in experimental group who revealed a naïve views about empirical aspect of NOS did not change significantly from post to follow-up measurement. Actually there were same numbers of participants in this level.

Similarly, the number of participants in experimental group who demonstrated a transitional views about empirical aspect of NOS did not change significantly from post to follow-up measurement, $\chi^2 = 1.33$, $p = .250$.

Likewise, there was not a significant change in the proportion of participants who articulated informed views after HOS instruction when compared with proportion of participants at follow-up measurement, $\chi^2 = 1.33$, $p = .250$.

At five-week follow-up test experimental group participants' NOS views regarding empirical aspect were similar to their post views. When students' responses investigated further, it was noticed that they also articulated quite similar responses from posttest to follow-up test. In other words if students were, for example, in transitional level at post measurement, they were most likely in transitional level at follow-up measurement too. The quotes below exemplify the similarity in the views of participants from posttest to follow-up measurement regarding empirical aspect of NOS. To present a clear picture, quote pairs including students' post and follow-up responses were provided.

Measurement	Item	Student's Response (E19)
Posttest	1	*Science looks for logical responses to different problem which arise in nature; and scientists try to find alternative explanations or solutions to those problem based on evidence....*
	2	*... In science, we search about what we don't know; but in art, music, and history we just learn things and we don't conduct research.*
Follow-up	1	*Science is the investigation of new things and learning of what we are not familiar with...*
	2	*The distinctive feature of science [from other subjects] is that we try to explore new things. In science we do research and seek for evidence and answers. But others [school subjects] do not include such things.*

In response to both first and second questionnaire items, participant 19 articulated informed empirical views at post-instruction and follow-up measurement. S/he defined science based on evidence and investigation. S/he also emphasized the role of research and evidence in science and attributed them as distinctive features of science from other disciplines.

The next participant also expressed informed views right after the instruction and five weeks after the instruction.

Measurement	Item	Student's Response (E21)
Posttest	1	*Science is the discipline that investigates the things that are unknown before...*
	2	*In science scientists seek for evidence around universe. This is what differentiates science from other school subjects.*
Follow-up	1	*I think that science means doing research and science is really important...*
	2	*Scientists always do a lot of research about the Earth and universe and this makes science distinctive among others.*

Based on the first and second questionnaire items, this participant's (E21) response revealed an informed understanding of empirical NOS at both measurements where s/he admitted that science requires doing research to address the natural phenomena. S/he also could differentiate science from other disciplines based on its empirical nature.

4.2.2.3.4 Empirical NOS Views of Comparison Group: Post-Instruction to Follow-up

This part presents comparison group participants' empirical views at post and follow-up measurements. The percent of students in each level right after the curriculum-oriented instruction and at follow-up measurement were given at Figure 4.29.

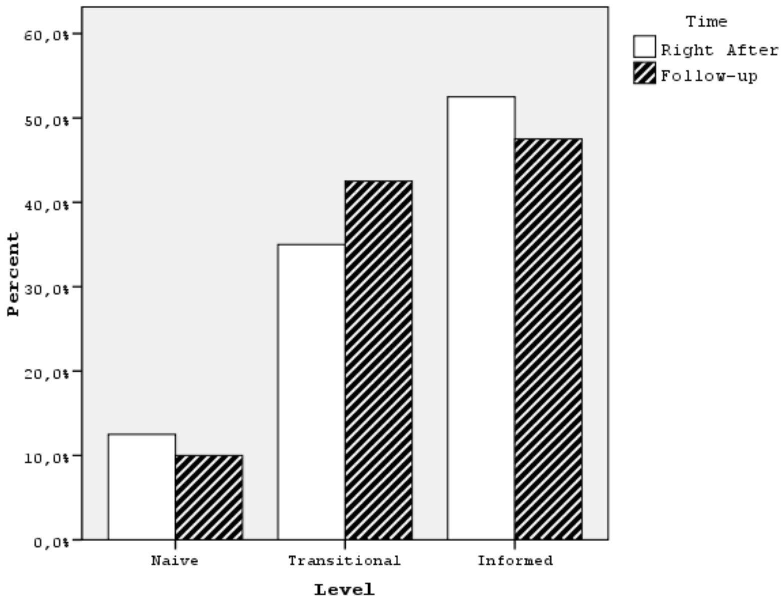

Figure 4.29 Comparison Group Participants’ Post and Follow-up Empirical Views (%)

When the bar graph examined, it was seen that there was a minor change in NOS views of students regarding empirical aspect of NOS from post measurement to follow-up measurement. The percent of participants in naïve and informed levels seemed to decrease slightly, but the proportion of participants holding transitional views slightly increased. There were 5 (13%) students who could not perceive the understanding of empirical NOS and articulated naïve views after the curriculum-oriented instruction and there were 4 (10%) at follow-up measurement. Correspondingly, there were 14 (35%) students who elucidated transitional views after the instruction while 17 (43%) students expressed the same views at follow-up. Twenty-one (53%) students, though, elucidated informed views after curriculum-oriented instruction while 19 (48%) students expressed informed views regarding empirical nature of science at follow-up measurement.

The difference between comparison group participants' empirical views from post measurement to follow-up measurement was again tested statistically using McNemar's test. Table 4.44 indicates the result of this comparison.

Table 4.81 McNemar Test Result of Comparison Group Participants' Post and Follow-up Empirical Views

Level	McNemar's Test*	Significance (p)
Naive	0.00	1.00
Transitional	1.33	.250
Informed	0.50	.500

*McNemar's Test Value has been calculated using Formula 2.

Table 4.70 shows that there was not a significant change in the proportion of participants who hold naïve views after curriculum-oriented instruction when compared with the proportion of participants at follow-up measurement, $\chi^2 = .00$, $p = 1.00$.

Similarly, the number of participants in comparison group who hold transitional views about empirical aspect of NOS did not change significantly from post measurement to follow-up measurement, $\chi^2 = 1.33$, $p = .250$.

Likewise, there was not a significant change in the proportion of participants who hold informed views after curriculum-oriented instruction when compared with proportion of participants at follow-up measurement, $\chi^2 = .50$, $p = .500$.

The statistical comparison showed that there was not a major variability in comparison group students' empirical views between two measurements. The following quote pairs also confirmed this consistency. Participant 59 in comparison group, for example, expressed transitional views at both post and follow-up measurement.

Measurement	Item	Student's Response (C59)
Posttest	1	*I see science as the collection of all attempts to prove events occurring in the universe...*
	2	*Science is different from other discipline in the following ways: in science, you can prove everything and set up experiments to test anything.*
Follow-up	1	*Science is the attempts of proving the accuracy or verifying the inaccuracy of the events in the universe by means of experiments...*
	2	*In science, you carry out experiments but in other school subjects you do not.*

Taking into account of responses to the first and second questionnaire item at VNOS-E, this students exhibited a transitional view of empirical NOS. S/he(C59) could differentiate science from other school subjects by emphasizing the role of experiments in science. However s/he was not able to mention the role of observation and evidence in scientific endeavor in both measurements.

The next participant articulated naïve empirical views in both post and follow-up measurements.

Measurement	Item	Student's Response (C77)
Posttest	2	*There is nothing that makes science different than other school subjects. They are all one of the school subjects and they are all identical…*
	4.b	*Scientists found the bones of dinosaurs and combine them. The appearance of dinosaurs emerged spontaneously..*
Follow-up	2	*Like many others, science course is taught in schools. We are responsible from science as other courses. It seems to me that it [science] is a bit more difficult than others.*
	4.b	*The fossils and the bones of dinosaurs were brought together by scientists, and this reveled their [dinosaurs] appearance.*

As it is apparent in her/his responses to both measurement, s/he (C77) equated science with other school subjects at both post and follow-up measurements. When discussing about dinosaurs, s/he also could not refer to the function of evidence. S/he neither referred to experiments nor observation and evidence in development of scientific knowledge. Therefore her/his response revealed her/his naïve understanding that s/he could not perceive the role of evidence in science.

4.2.2.4 Within Group Comparisons: Creative and Imaginative Aspect of NOS

Basically, students' creative and imaginative NOS conceptions were evaluated using seventh questionnaire item which asks "*Do you think scientists use their imaginations when they do their work? If No, explain why? If Yes, then when do you think they use their imaginations?*". Some students responses to fourth, fifth and sixth questionnaire item also provided evidence for their creative and imaginative NOS conceptions (see section 4.2.2.2 for these items).

4.2.2.4.1 Creative and Imaginative NOS Views of Experimental Group: Pre to Post-Instruction

Under this caption, experimental group participants NOS conception regarding creative and imaginative aspect were discussed based on their pre- and post-instruction views. Before introducing the result of statistical comparison, the proportions of participants were presented for each level through bar graph in Figure 4.30.

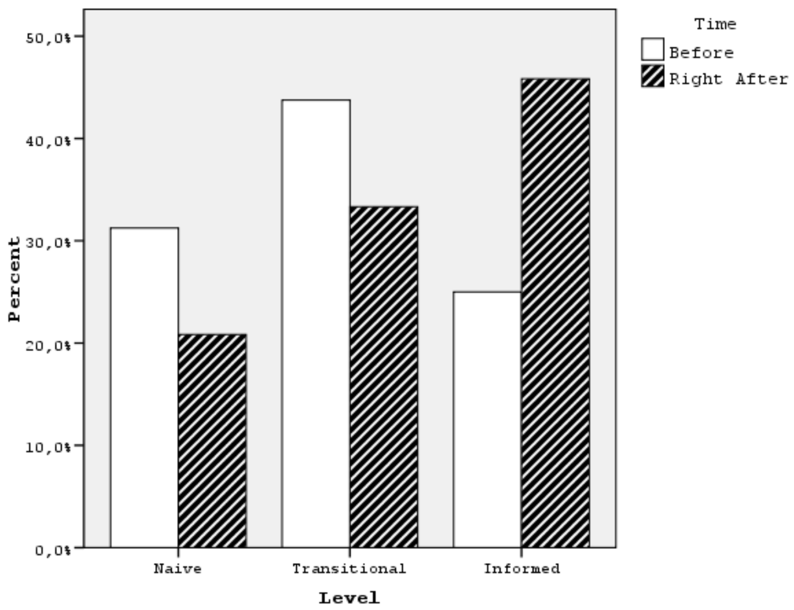

Figure 4.30 Experimental Group Participants' Pre and Post Creative and Imaginative Views (%)

Bar graph clearly indicates that the proportion of participants elucidating naïve and transitional views decreased, while the proportion of participants articulating informed views increased right after the HOS instruction. Before instruction, 15

(31%) students held naïve views. This number decreased to 10 (21%) after HOS instruction. Similarly, 21 (44%) students articulated transitional views before instruction, and 16 (33%) students elucidated transitional views after HOS instruction. In terms of informed views, 12 (25%) students expressed informed views prior to instruction while ten more students (22 in total) articulated informed views after HOS instruction.

This result implied that HOS instruction may enhance developed creative and imaginative views. This effect was tested using McNemar's test. Table 4.71 shows the result of the statistical comparison.

Table 4.82 McNemar Test Result of Experimental Group Participants' Pre and Post Creative and Imaginative Views

Level	McNemar's Test*	Significance (p)
Naive	1.78	.180
Transitional	.94	.332
Informed	4.5	.031

*McNemar's Test Value has been calculated using Formula 2.

Table 4.71 indicates that the proportion of participants in experimental group who elucidated naïve views, $\chi^2 = 1.78$, $p = .180$; and transitional views, $\chi^2 = .94$, $p = .332$ about creative and imaginative view did not change significantly right after HOS instruction compared to prior to instruction. On the other hand, there was a significant increase in the proportion of participants who articulated informed views after HOS instruction, $\chi^2 = 4.5$, $p = .031$. Participants were more likely demonstrated an informed view of creative and imaginative NOS after HOS instruction (46%) than before HOS instruction (25%).

The following quote pairs show how the participants' views on creative and imaginative aspect developed from pre to post-instruction in experimental group.

Measurement	Item	Student's Response (E42)
Pretest	4.b	*Scientists have conducted scientific research; therefore they are sure about dinosaurs' appearance...*
	7	*No I don't think that scientists use their imaginations when they do their work. They inform us about the knowledge they obtain. If they incorporated it [creativity and imagination] into their work, then we would have incorrect knowledge.*
Posttest	4.b	*Scientists may not be exactly sure about dinosaurs' appearance. On the one hand they [scientists] seem to be created dinosaurs' appearance. On the other hand it was reported that they once lived on the Earth through photography and etc....*
	7	*Yes I believe that scientists use their imagination... I think that scientists utilize creativity and imagination during the beginning of any scientific study.*

Before HOS instruction, student 42 elucidated naïve views regarding creative and imaginative NOS. S/he seemed to believe that scientists know surely about dinosaurs because they conduct scientific research. S/he did not make reference to the role of creativity and imagination in science. S/he also explicitly stated that creativity and imagination would make scientists to arrive wrong conclusions. But after HOS instruction s/he articulated transitional views regarding the same aspect. S/he seemed to have undecided about the role of creativity and imagination in science. S/he could not decide whether scientists use their creativity or whether they only report what they see. S/he also stated that early stage of scientific investigations include those skills.

Student 44 was another example showing that how students in experimental group improved their views after the instruction.

Measurement	Item	Student's Response (E44)
Pretest	7	*I believe that they [scientists] may use [their creativity and imagination] in planning their research. Because in planning imagination works best. I don't think that scientists use their creativity in other phases.*
Posttest	6	*I think they [weather people] are not totally sure about it [weather pictures]. They are creating different scenarios about weather and they are reporting which seems more rational to them...*
	7	*In my point of view they [imagination and creativity] are used in all phase like planning and interpretation of results. In order to create new things they [scientists] have to be creative.*

Student 44 expressed transitional views before HOS instruction while s/he articulated informed views after the instruction. At the beginning of the study s/he expressed that scientists use their imagination and creativity only in some particular phase of their studies. S/he continued that scientists use them while planning and conducting experiments. Right after the instruction, s/he explicitly stated that scientists are supposed to have those characteristics. S/he also added that different parts of scientific research include different creative and imaginative components. S/he concluded that scientists should be creative to generate new things.

4.2.2.4.2 Creative and Imaginative NOS Views of Comparison Group: Pre to Post-Instruction

In this part, comparison group participants' creative and imaginative NOS views were expressed by evaluating their pre- and post-instruction views. To remind, the percent of participants in each level, the result of statistical test results, and example quotes were provided respectively to be consistent in presentation. Bar graph in Figure 4.31 shows the proportion of participants holding naïve, transitional, and informed creative and imaginative views before and after curriculum-oriented instruction.

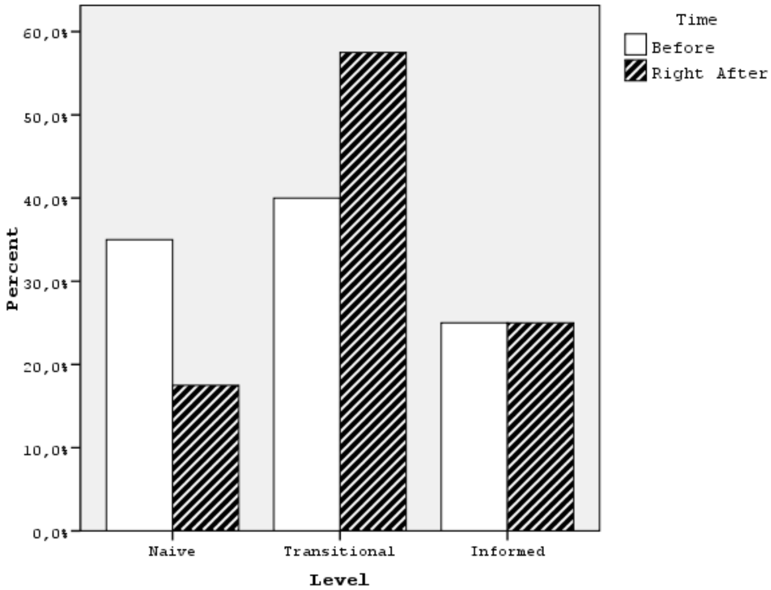

Figure 4.31 Comparison Group Participants' Pre and Post Creative and Imaginative Views (%)

There were 14 (35%) students who articulated naïve views before the curriculum-oriented instruction. This number reduced to 10 (21%) after the instruction. The number of participants in transitional level increased from pre-instruction (40%) to post-instruction (58%). There was no change in the proportion of students having informed views (25%).

The effect of curriculum-oriented instruction on students' creative and imaginative view was tested using McNemar's test. Table 4.72 shows the result of the comparison before and after curriculum-oriented instruction based on each level.

Table 4.83 McNemar Test Result of Comparison Group Participants' Pre and Post Creative and Imaginative Views

Level	McNemar's Test*	Significance (p)
Naive	2.12	.143
Transitional	1.89	.167
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.72 reveals that the proportion of participants in comparison group who demonstrated a naïve (χ^2 = 2.12, p = .143), transitional (χ^2 = 1.89, p = .167), and informed views (χ^2 = .00, p = 1.000) about creative and imaginative aspect of NOS did not change significantly from pre to post-instruction.

Following quote pairs demonstrates some of the students' views before and after curriculum-oriented instruction. It was evident in those students' responses that comparison group students could not make progress in their views regarding creative and imaginative NOS after the instruction.

Measurement	Item	Student's Response (C78)
Pretest	7	*I don't think that they [scientists] are using their creativity or imagination because science is not a fictitious thing.*
Posttest	7	*Scientists should always seek for reality; therefore I don't think they use their creativity or imagination.*

Student 78 articulated naïve views before and after curriculum-oriented instruction. It was apparent in her/his response to the seventh questionnaire item that s/he did not believe in the role of creativity and imagination in generating scientific knowledge both at pre and post measurements.

Following student (C71) also expressed similar views before and after curriculum-oriented instruction.

Measurement	Item	Student's Response (C71)
Pretest	7	*Yes. Scientists use their imagination in planning and in conducting experiments. By this way they decided on how to precede their work. But scientists are supposed to be objective in other phases such as reporting their result...*
Posttest	7	*Of course scientists use their creativity and imagination in their study. They hypothesize what to research and then conduct their experiments. I think they use their imagination during stating hypothesis and their creativity during experiments. But final part should be imaginative and creativity free...*

Before the instruction s/he expressed that scientists use their imagination and creativity only in some particular phase of their studies, planning and conducting experiments. After the instruction, s/he accepted the role of creativity and imagination as well; but stated that scientists use them only during hypothesizing and conducting experiments.

4.2.2.4.3 Creative and Imaginative NOS Views of Experimental Group: Post-Instruction to Follow-up

In the following part, experimental group participants' creative and imaginative NOS views were discussed by comparing their views at post and follow-up measurements. The relative proportion of students in each level right after the HOS instruction and at follow-up measurement were given at Figure 4.32. The bar graph indicates that there was a minor change in the number of students who elucidated naïve and transitional views, and no change was observed in informed level. Actually, there were 10 (21%) students holding naïve views after the instruction while 11 (23%) students demonstrated a naïve creative and imaginative views at follow-up measurement. The number of participants articulating transitional views decreased 16 (33%) to 15 (31%) from post to follow-up measurement. There were 22 (46%) students at post and follow-up measurement in informed level.

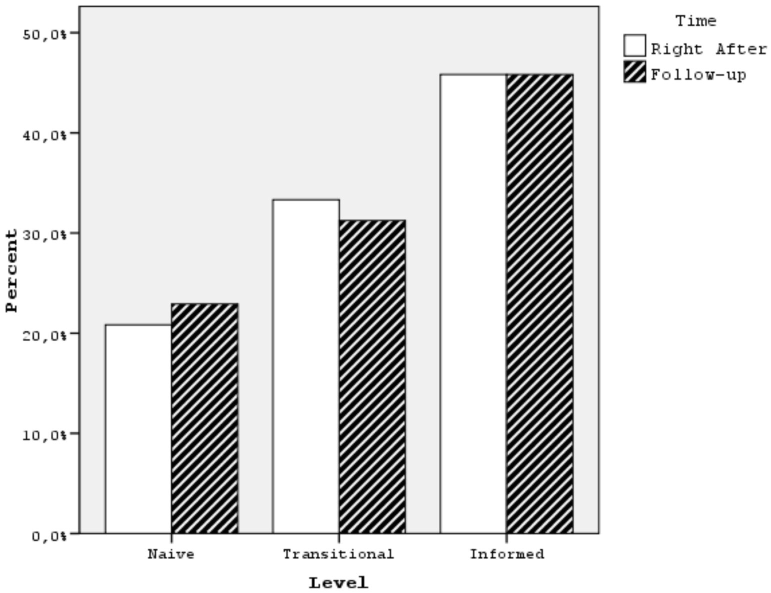

Figure 4.32 Experimental Group Participants' Post and Follow-up Creative and Imaginative Views (%)

The difference between experimental group participants' creative and imaginative views from post to follow-up measurement was tested statistically using McNemar's test and the result was tabulated at Table 4.73.

Table 4.84 McNemar Test Result of Experimental Group Participants' Post and Follow-up Creative and Imaginative Views

Level	McNemar's Test*	Significance (p)
Naive	.00	1.000
Transitional	.00	1.000
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.73 displays that the proportion of participants in experimental group who held naïve (χ^2 = .00, p = 1.000), transitional (χ^2 = .00, p = 1.000), and informed views (χ^2 = .00, p = 1.000) about creative and imaginative aspect of NOS did not change significantly from post to follow-up measurement.

This result indicated that at five-week follow-up measurement, experimental group participants' NOS views regarding creative and imaginative aspect were similar to their post views. When students' responses investigated further, it was noticed that they articulated quite parallel responses at both measurements. The quotes below illustrates that experimental group students retained their post-instruction views five week after the instruction.

Measurement	Item	Student's Response (E8)
Posttest	7	*Yes, they [scientists] use creativity and imagination. Imagination is one of the central characteristics that a scientist should have. Only in this way scientist may be creative, comes up with new ideas, defends her/his ideas, and designs experiments to test those ideas.*
Follow-up	7	*I think that scientific research includes using both creativity and imagination. Without creativity and imagination scientists could fail to create original ideas. Therefore they use their creativity and imagination always.*

While responding to the seventh questionnaire item, which ask whether scientists use their imagination, the students above (E8) seemed to comprehend creative and imaginative NOS at both measurements. In her/his post-instruction response, s/he indicated that science includes creative and imaginative components and s/he added that scientists come up with new ideas by being creative. S/he retained her/his informed views at follow-up measurement. S/he expressed that creativity and imagination are needed in every aspect of a scientist's work. S/he also explicitly stated that imagination and creativity facilitate scientists' job in terms of creating original ideas. In brief s/he elucidated informed views at both measurements.

Following student (E46) also expressed an adequate view at post and follow-up measurements.

Measurement	Item	Student's Response (E8)
Posttest	7	*Yes, scientists use their imaginations when they do their work. If they don't use their imagination they don't know and cannot understand what to do. So they are using their imaginations...*
Follow-up	7	*Of course they [scientists] use them [creativity and imagination]. Otherwise they can't know what to do and how to do...*

This participant admitted that scientists should have creativity and imagination in order to do science at post and follow-up measurements. In other words S/he could retain her/his informed view point about creative and imaginative NOS five-week after HOS instruction.

4.2.2.4.4 Creative and Imaginative NOS Views of Comparison Group: Post-Instruction to Follow-up

In this part, the understanding of comparison group participants' post-instruction and follow-up views were explained based on their creative and imaginative conceptions. The percent of students in each level right after the curriculum-oriented instruction and at follow-up measurement were given at Figure 4.33.

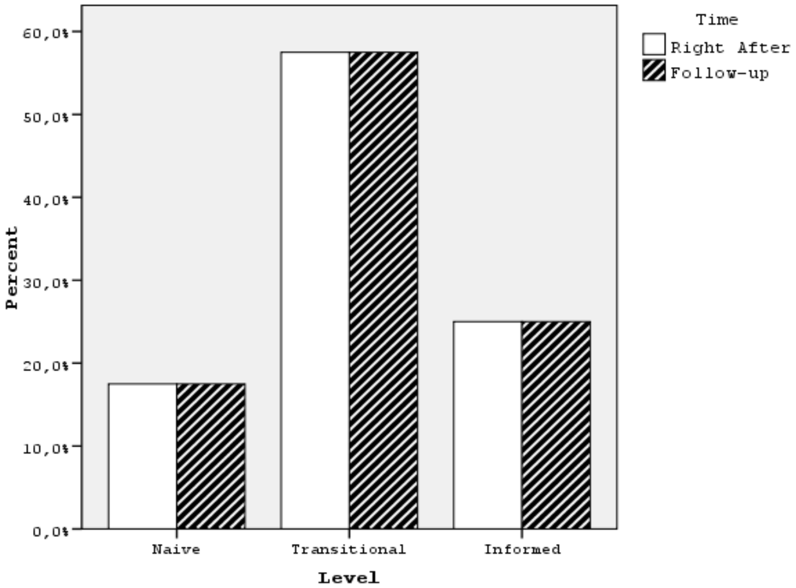

Figure 4.33 Comparison Group Participants' Post and Follow-up Creative and Imaginative Views (%)

The figure indicates that there was no change in NOS views of students regarding creative and imaginative aspect of NOS from post measurement to follow-up measurement. There were 7 (18%) students articulating naïve views; 23 (58%) students elucidating transitional views; and 10 (25%) students reflecting informed views at post-and follow-up measurement respectively. Because of finding no change, it is not required to test the statistical difference.

Following quote pairs also supported that comparison group participants preserve their understanding of creative and imaginative NOS at five-week follow-up measurement.

Measurement	Item	Student's Response (C53)
Posttest	6	*Weather people are 100% sure about weather pictures which shows how weather will be for the next day because of advanced tools, such as satellites [artificial ones]...*
	7	*Scientists don't use them [creativity and imagination] because science is not a subject that can be risked. Such issues [scientific issues] should be tested precisely and hypothesis should not be publicized.*
Follow-up	4.b	*Scientists are sure about dinosaurs' appearance because their appearance can easily be noticed from their skeleton...*
	7	*I don't think they [scientists] use their creativity and imagination, because precise results cannot be achieved with them.*

Student 53 elucidated naïve views at both post and follow-up measurements. Her/his post-instruction response referred that technological apparatus enable scientists to find what the truth is. S/he also explicitly stated that creativity and imagination is a danger for the confidence of people to science. Correspondingly her/his follow-up response demonstrated her/his view point that evidence allows scientists to find the truth, without using creativity and imagination.

It was apparent in the next participant's response that s/he holds transitional views about the same aspect at both measurements.

Measurement	Item	Student's Response (C71)
Posttest	7	*Of course scientists use their creativity and imagination in their study. They hypothesize what to research and then conduct their experiments. I think they use their imagination during stating hypothesis and their creativity during experiments.*
Follow-up	7	*Science is the study of what you imagine... Prior stages of science require creativity and imagination. But when you make progress, you have to leave your interpretation and you have to be focus on what the evidence says.*

Right after the instruction, student 71 accepted the role of creativity and imagination; but stated that scientists use them only during hypothesizing and conducting experiments. At follow-up measurement, s/he could demonstrate an understanding of the role of creativity and imagination as well. However, s/he expressed that scientists use those skills only during the early stage of their studies.

Student 69 articulated informed creative and imaginative views in both post and follow-up measurements.

Measurement	Item	Student's Response (C69)
Posttest	7	*Yes. To me, they [scientist] use them [creativity and imagination] in every phase of their research. If they don't use their imagination, they can't create any original ideas...*
Follow-up	7	*Scientists use imagination and creativity in every step, for example in planning, experimentation, data analysis and etc. As a result they produce different innovative ideas and present them to society.*

It is clear that student 69's responses made reference to creative and imaginative aspect of NOS at both measurements. At her/his post-instruction response s/he stated that scientists could construct original idea by being creative. At follow-up measurement s/he could also articulated that creativity and imagination are needed in every aspect of a scientist's work. S/he explicitly stated that imagination and creativity facilitate scientists' job in terms of creating original ideas.

4.2.2.5 Within Group Comparisons: Inferential Aspect of NOS

Students' inferential views were assessed based on their responses to fourth, fifth and sixth questionnaire items (see section 4.2.2.2 for these items).

4.2.2.5.1 Inferential NOS Views of Experimental Group: Pre to Post-Instruction

The proportion of participants who held naïve, transitional and informed views regarding inferential aspect before and after HOS instruction were presented for each level through bar graph in Figure 4.34.

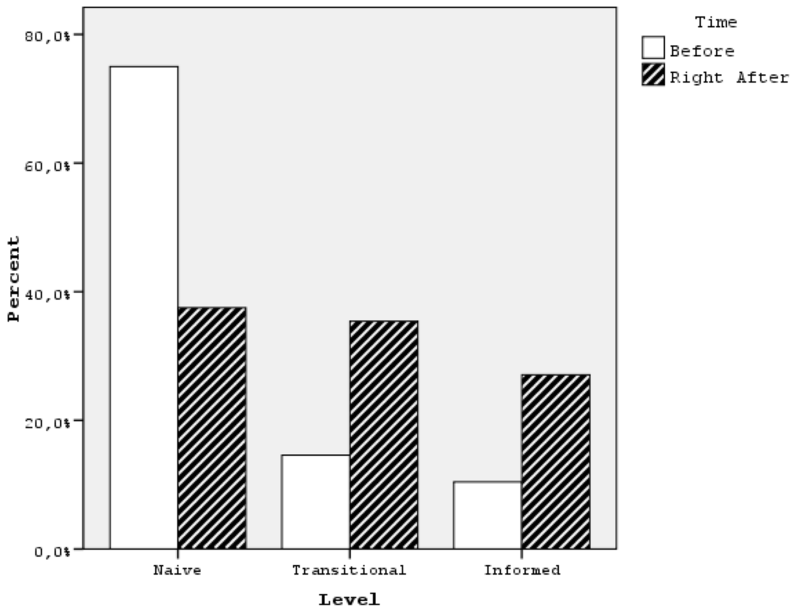

Figure 4.34 Experimental Group Participants' Pre and Post Inferential Views (%)

Bar graph in Figure 4.34 indicates that the proportion of participants holding naïve views decreased, while the proportion of participants articulating transitional and informed views increased right after the HOS instruction. Before the instruction, 36 (75%) students held naïve views while18 (38%) students expressed naïve views after HOS instruction. Nevertheless, 7 (15%) students articulated transitional views before instruction. This number increased to 17 (35%) after HOS instruction. Compared to 5 (10%) students prior to instruction, the number of students who articulated informed views increased to 13 (27%) after HOS instruction.

The effect of HOS instruction on students' inferential views was tested statistically using McNemar's test. Table 4.74 shows the result of the comparison before and after HOS instruction in each level.

Table 4.85 McNemar Test Result of Experimental Group Participants' Pre and Post Inferential Views

Level	McNemar's Test*	Significance (p)
Naive	16.06	.000
Transitional	4.50	.031
Informed	4.90	.021

*McNemar's Test Value has been calculated using Formula 2.

The above table indicates that the proportion of participants in experimental group who held naïve views, $\chi^2 = 16.06$, $p < .0005$; transitional views, $\chi^2 = 4.50$, $p = .031$; and informed views, $\chi^2 = 4.90$, $p = .021$ about inferential aspect of NOS changed significantly right after HOS instruction.

The following quotes show how the participants' views on inferential aspect of NOS developed from pre to post-instruction in experimental group.

Measurement	Item	Student's Response (E9)
Pretest	4.b	*Scientists are certain about it [the way dinosaurs looked]... Dinosaurs' traces reveal their appearance.*
Posttest	4.b	*By combining the parts of skeleton, scientists created possible appearance of dinosaurs. In this way they gained knowledge [about dinosaurs' appearance]. I think they are not sure about it because those shapes are scientists own creation.*

This student (E9) elucidated naïve views before HOS instruction. S/he could seem not to comprehend the distinction between observation and inference before the instruction. S/he held the conception that evidence is the only way to create scientific explanations. But after HOS instruction s/he could demonstrate an informed conception about the distinction between observation and inference. S/he expressed that scientists utilize part of dinosaurs' skeleton and make grounded estimation to tell how dinosaurs looked like.

It was also evident in the following student's (E27) response that experimental group student could expressed more adequate understanding about the distinction between observation and inference after HOS instruction.

Measurement	Item	Student's Response (E27)
Pretest	4.b	*They [scientists] are not totally sure about the way dinosaurs looked. Because they [scientists] didn't see them [dinosaurs].*
Posttest	4.b	*They [scientists] are struggling to join the different fossils of dinosaurs together. Scientists don't have all the information about them. Based on what they have, they are trying to estimate their appearance*

This students articulated naïve and informed views before and after the instruction respectively. Before HOS instruction s/he held the stereotypic naïve conception that "knowing is seeing". After HOS instruction, however, s/he could demonstrate informed understanding of the distinction between observation and inference in the construction of scientific explanations. In her/his post response, s/he referred that scientists are attempting to estimate dinosaurs' appearance (inference) based on studying ever found dinosaurs' fossils (observation).

4.2.2.5.2 Inferential NOS Views of Comparison Group: Pre to Post-Instruction

During the following part, the evaluation of comparison group participants' inferential NOS views were presented based on their pre- and post-instruction views. Bar graph in Figure 4.35 shows the proportion of participants holding naïve, transitional, and informed inferential views before and after the curriculum-oriented instruction.

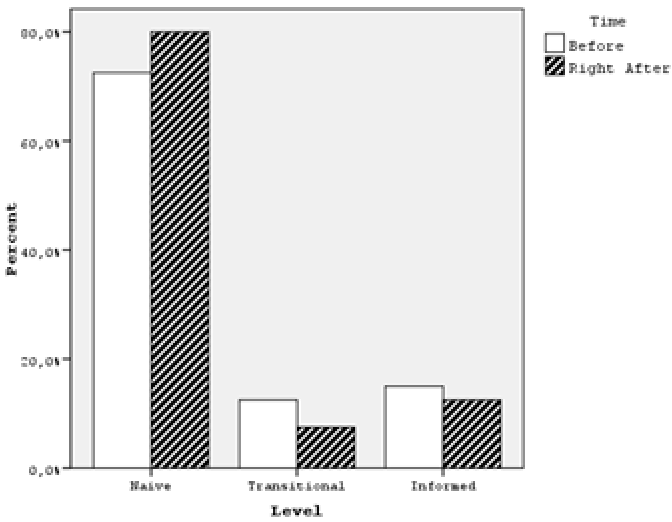

Figure 4.35 Comparison Group Participants' Pre and Post Inferential Views (%)

As seen in the bar graph, there were 29 (73%) students holding naïve views before the curriculum-oriented instruction. This number increased to 32 (80%) after the instruction. The number of participants in transitional level decreased from pre-instruction (5 students) to post-instruction (3 students). There was also a slight decrease in the proportion of students having informed views from pre-instruction (15%) to post-instruction (13%).

The effect of curriculum-oriented instruction on students' inferential view was tested using McNemar's test. Table 4.75 shows the result of the comparison before and after curriculum-oriented instruction according to each level.

Table 4.86 McNemar Test Result of Comparison Group Participants' Pre and Post Inferential Views

Level	McNemar's Test*	Significance (p)
Naive	.27	.607
Transitional	.17	.687
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.75 reveals that the proportion of participants in comparison group who held naïve (χ^2 = .27, p = .607), transitional (χ^2 = .17, p = .687), and informed views (χ^2 = .00, p = 1.000) about inferential aspect of NOS did not change significantly from pre to post-instruction.

The following quote pairs show how the participants' view on inferential aspect was consistent from pre to post-instruction in comparison group. Participant 59 expressed naïve views before and after curriculum-oriented instruction.

Measurement	Item	Student's Response (C59)
Pretest	4.a	*...by analyzing the bones of dinosaurs which dates from past, they [scientists] have had information about their [dinosaurs] existence on the Earth.*
	4.b	*They [scientists] are conducting DNA tests on the bones [fossils] of dinosaurs. By this way they obtain their appearance accurately.*
Posttest	4.a	*Geologists found the traces of dinosaurs under the soil and scientists analyze them in the laboratories. They have discovered their existence by this way...*
	4.b	*...They [scientists] also examined their DNA sequence and found how they [dinosaurs] appeared.*

Students 59 believed that direct evidence is the only source of scientific knowledge and nothing else is relevant to scientific explanations. Her/his response illustrated her/his understanding of science as strictly evidence based. S/he could not demonstrate an understanding that scientists inferred the way dinosaurs looked by grounding their inference to fossils of dinosaurs. In brief, s/he could not demonstrate an adequate understanding of the distinction between observation and inference at both measurements.

The following quote pairs also demonstrate how comparison group participants' view on inferential aspect was consistent from pre to post-instruction. Her/his response exhibited a transitional view of inferential NOS at both measurements.

Measurement	Item	Student's Response (C54)
Pretest	4.b	*When scientists make excavation, they found the fossils of dinosaurs. They are bringing scattered bones together and estimating the way they looked...*
	6	*Meteorologists are sending balloons to air and the devices inside the balloon measures the weather exactly. Experts are sharing this information with the society too.*
Posttest	4.b	*Scientists study on dinosaurs traces. They [scientists] don't have definite information about their [dinosaurs] appearance. They are trying to estimate it...*
	6	*Weather experts are sending white balloons to the air every day and week. Those balloons are measuring the weather. By this way they [weather people] are certain about weather pictures.*

Before and right after curriculum-oriented instruction, student 54 could demonstrate an understanding of inferential nature of scientific knowledge in the case of dinosaurs, but s/he could not exhibit the same understanding in the case of weather pictures. In other words s/he articulated transitional views regarding inferential NOS at both measurements.

4.2.2.5.3 Inferential NOS Views of Experimental Group: Post-Instruction to Follow-up

In the following part, experimental group participants' inferential NOS views were explained by comparing their post-instruction and follow-up views. The relative proportion of students in each level right after the HOS instruction and at follow-up measurement was given at Figure 4.36.

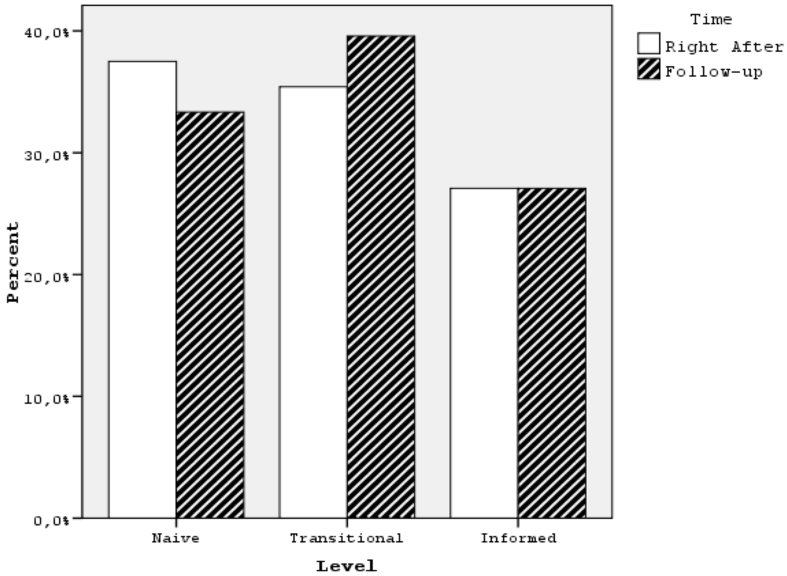

Figure 4.36 Experimental Group Participants' Post and Follow-up Inferential Views (%)

It indicates that there was a small change in students' naïve and transitional views regarding inferential aspect of NOS from post-instruction to follow-up measurement. In turn, no change was found the number of students who elucidated informed views. There were 18 (38%) students holding naïve views after instruction while 16 (33%) students expressed naïve inferential views at follow-up. Seventeen (35%) students articulated transitional views right after the instruction while 19 (40%) students expressed transitional views at follow-up. Conversely, as mentioned above, the proportion of participants having informed views did not change. There were 13 (27%) students holding informed views at post and follow-up measurements.

The difference between experimental group participants' inferential views from post to follow-up measurement was tested statistically using McNemar's test which was provided in Table 4.76.

Table 4.87 McNemar Test Result of Experimental Group Participants' Post and Follow-up Inferential Views

Level	McNemar's Test*	Significance (p)
Naive	.50	.500
Transitional	.50	.500
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.76 displays that the proportion of participants in experimental group who revealed naïve (χ^2 = .50, p = .500), transitional (χ^2 = .50, p = .500), and informed views (χ^2 = .00, p = 1.000) about inferential aspect of NOS did not change significantly from post to follow-up measurement.

At five-week follow-up test, experimental group participants' NOS views regarding inferential aspect were similar to their post views. When students' responses investigated further, it was noticed that they articulated comparable responses at both measurement. The quotes below exemplify the similarity in the views of participants from posttest to follow-up measurement.

Measurement	Item	Student's Response (E1)
Posttest	4.b	*I think that they [scientists] don’t know for certain about dinosaurs’ appearance. Only, they make prediction based on their [dinosaurs] fossils...*
	6	*They [weather people] are sure about weather pictures because they use various tools to observe the weather...*
Follow-up	4.b	*Taking into account their [dinosaurs’] fossils, they [scientists] make prediction about their [dinosaurs] looking. I mean, they [scientists] are not totally sure about it...*
	6	*For this purpose [to measure weather] they [weather people] use different tools. I think they are sure about them because those are very sensitive instruments.*

Student 1 could demonstrate transitional understanding of the distinction between observation and inference at post-instruction and follow-up measurements. Right after the instruction s/he could express an adequate understanding in the case of dinosaurs' appearance, but s/he could not exhibit the same understanding in the case of weather pictures. At follow-up measurement s/he, similarly, elucidated adequate views in the case of dinosaurs. S/he indicated that scientists deduce dinosaurs' looking based on their fossils. But in the case of weather pictures, s/he could not exhibit the same level of understanding. S/he believed that sensitive instruments enabled weather expert to make precise measurement without requiring inferential approximation.

The next participant (E27) also expressed informed views right after the instruction and five weeks after the instruction.

Measurement	Item	Student's Response (E27)
Posttest	4.b	*They [scientists] are struggling to join the different fossils of dinosaurs together... Scientists don't have all the information about them [dinosaurs]. Based on what they have, they are trying to estimate their appearance.*
Follow-up	4.b	*By combining the different bones together, scientists learn something about the appearance of dinosaurs. They cannot have a full knowledge about it because different scientists could draw different conclusions from them [fossils].*

Student 27 could demonstrate informed understanding of the distinction between observation and inference in both measurements. S/he stated that scientists investigate the fossils and bones of dinosaurs (observation) and work out their appearance (inference).

4.2.2.5.4 Inferential NOS Views of Comparison Group: Post-Instruction to Follow-up

Similar to the previous part, this part addressed the understanding of comparison group participants' post and follow-up inferential views. As a reminder, the percent of participants in each level (naïve, transitional, and informed), the result of statistical test, and example quotes exemplifying the change (or consistency) were provided in order. The percent of students in each level right after the curriculum-oriented instruction and at five-week follow-up measurement were given at Figure 4.37.

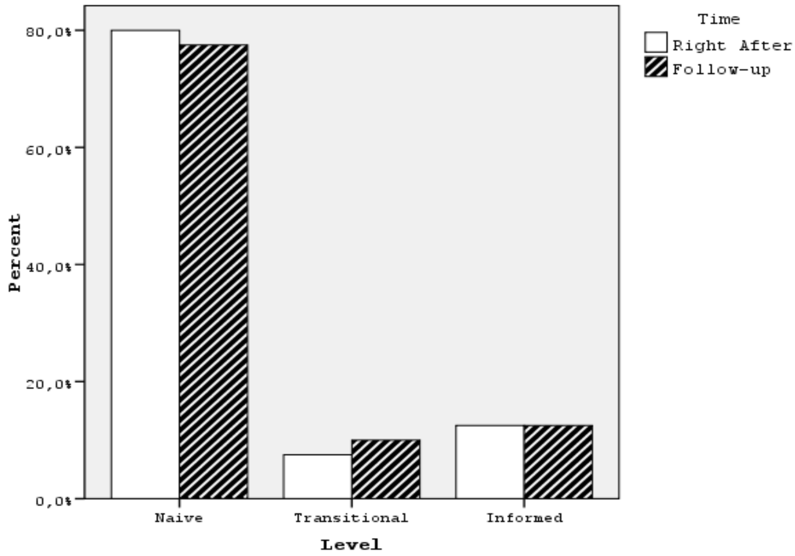

Figure 4.37 Comparison Group Participants' Post and Follow-up Inferential Views (%)

The bar graph above indicates that there was only a minor change in students' naïve and transitional views regarding inferential aspect of NOS from post-instruction to follow-up measurement. When the bar graph was inspected, it was found that there were 32 (80%) students who did not perceive the distinction between observation and inference; that is, they demonstrated a naïve inferential views after curriculum-oriented instruction. In turn,31 (78%) students' responses reflected their naïve views regarding inferential nature of science at follow-up measurement. The number of participants whose response exhibited a transitional view of inferential NOS seemed to increase slightly. Only 3 (8%) students reflected their transitional views right after curriculum-oriented instruction. In response,4 (10%) students expressed transitional views at follow-up measurement. Conversely the proportion of participants who could differentiate the distinction between observation and inference did not change from post-instruction to follow-up measurement. There were 5 (13%) students who at both measurements.

The effect of curriculum-oriented instruction on students' inferential view was tested using McNemar's test. Table 4.77 shows the result of the comparison between post- instruction and follow-up measurements based on each level.

Table 4.88 McNemar Test Result of Comparison Group Participants' Post and Follow-up Inferential Views

Level	McNemar's Test*	Significance (p)
Naive	.00	1.000
Transitional	.00	1.000
Informed	.00	1.000

*McNemar's Test Value has been calculated using Formula 2.

Table 4.77 reveals that the proportion of participants in comparison group who held naïve, transitional, and informed views about inferential aspect of NOS did not change significantly from post-instruction to follow-up measurement (χ^2 = .00, p = 1.000).

The statistical comparison showed that there was not variability in comparison group students' views of the distinction between observation and inference from post measurement to follow-up measurement. The following quote pairs also verified this consistency. Participant 65 in comparison group expressed naïve views at both post and follow-up measurement.

Measurement	Item	Student's Response (C65)
Posttest	4.b	*With the help of fossils scientists know dinosaurs' appearance... After conducting a lot of research scientists provide information to public. In other words they are sure.*
Follow-up	4.b	*Scientists are sure about the way dinosaurs looked because fossils provided scientists information about their [dinosaurs] appearance. They also conducted other research about this topic*

This student's (C65) response at both measurements illustrated her/his acceptance of science as rigorously evidence based, without involving human inference. Her/his response referred that direct evidence is the single basis of scientific knowledge and nothing else is relevant to scientific explanations.

The next participant articulated informed inferential views in both post and follow-up measurements. Her/his post and follow-up response also indicate how comparison group participants' view on inferential aspect was consistent from post to follow-up measurement.

Measurement	Item	Student's Response (C68)
Posttest	4.b	*Scientists are familiar with dinosaurs [dinosaurs' appearance] by means of excavation, fossils and adding their inference to what they have...*
	6	*Meteorological service send balloon to the air and predict weather based on it...*
Follow-up	4.b	*It was found some of the bones and fossils of dinosaurs. Based on those bones and fossils, scientists form an opinion about the way dinosaurs' looked. Therefore they don't have definite answer.*
	6	*They [weather people] are sending air balloon and it obtain some information. Based on those information, they make prediction.*

Students 68 could demonstrate informed understanding of the distinction between observation and inference in the construction of scientific explanations at both measurements. In her/his post response, s/he explicitly stated that scientists use their inference in the case of how dinosaurs looked. S/he also referred to inferential NOS in weather forecast case. In her/his follow-up response, s/he also discussed that scientists investigate the fossils and bones of dinosaurs (observation) and work out their appearance (inference).

Summary of Findings

So far, the groups' pre, post and follow up tests scores regarding attitudes toward science, understanding of circulatory system concepts, science process skills, and nature of science views were presented. First, the result of one-way MANOVA was presented in relation to the pretest scores of the groups in order to show whether there was any significant preexisting difference between experimental and comparison group in terms of aforementioned collective DVs. To recall, this analysis was conducted because participants' prior attitude, prior science process skills and/or prior content knowledge may affect their posttest and/or follow-up test scores. The result showed that, there was not a statistically significant difference between experimental group and comparison group in terms of combined DVs prior to treatments. Moreover, Pearson Chi-square Test pointed out that there was not a substantial preexisting difference between the groups' views regarding tentative, subjective, empirical, creative and imaginative, and inferential nature of science. This result implied that the experimental and comparison group were similar in terms of their science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science views prior to the treatments.

Second, the results of Repeated-Measures MANOVA, which multivariately analyzed the groups' pretest, posttest, and follow-up scores on SPST, CSCT, and TOSRA, were presented. This was the main analysis and tested "to what extent HOS instruction and curriculum-oriented instruction create different profiles on the collective dependent variables of science process skills, understanding of human circulatory system concepts, and attitudes toward science across three testing conditions". The parallelism test produced statistically significant result with respect to combined DVs. It means that there were statistically significant differences among two groups in their profiles on the combined DVs. This result implied that HOS based instruction and curriculum-oriented instruction had created different profiles regarding three core dimension of scientific literacy with the time; and the magnitude of this nonparallel profile was not small. Repeated-Measures MANOVA gave an overall difference between groups. In order to pinpoint the sources of variability, contrasts were needed to discover which DV created the difference between groups. Therefore further contrasts were conducted for each DV separately and results were provided.

First contrast was conducted using science process skill test scores. Mixed between-within subjects of ANOVA results showed that interaction effect for the types of instruction and time in terms of SPST scores was not significant.

Similarly, the main effects for time and group were not significant. These results implied that there was not enough evidence to conclude that one of the instructions has superiority over the other in terms of improving science process skills. In other words the change in SPST scores over time was similar for HOS based and curriculum-oriented instructions.

The second contrast was conducted for science concepts understanding on circulatory system topic across time. Mixed between-within subjects of ANOVA yielded a significant interaction effect between the types of instruction and time in terms of CSCT scores. It means that there was not the same change in scores of CSCT over three time periods for two groups. The profile plot was examined for interaction effect and it was observed that as the students progress through time, the gap between mean scores of the groups broadened. More specifically, the students receiving HOS instruction increasingly outperformed over the students receiving curriculum-oriented instruction on circulatory system concepts test as the time passes. Thus, it was noticed that students in HOS classes retained key concepts of circulatory system better than students in other classes. Indeed, further statistical analysis for this interaction showed that although the mean difference between posttest scores of CSCT was not statistically significant for experimental and comparison groups, the mean follow-up scores of experimental group was significantly higher than that of comparison group. The magnitude of this mean difference was large. This finding implied that the difference found between the experimental and comparison groups at follow-up test arouse from the natures of treatment and this difference has practical value in terms of retaining content knowledge. In other words it is proper to conclude that HOS based instruction enabled better retention of science content knowledge than curriculum oriented instruction.

Lastly, in order to find out the relative effectiveness of two types of instruction on improving students' attitudes toward science across three time periods, another mixed between-within subjects of ANOVA was run. According to result, there was a statistically significant interaction between the types of instruction and time in terms of TOSRA scores. It means that the change in attitudes of students' toward science was different over three time periods for the groups. When the profile plot was inspected, it was noticed that although both groups showed an increase in TOSRA scores just after the treatments, the increase was sharper in experimental group. Further statistical investigation revealed that the mean difference between experimental group and comparison group in terms of posttest scores of TOSRA reached statistical significance. Similarly TOSRA scores of the experimental group were significantly higher than comparison group five weeks after the treatments. These results suggested that HOS instruction promoted favorable attitudes toward science than curriculum-oriented instruction just after the treatment and also experimental group still exhibited more positive attitudes toward science compared to comparison groups even five-week after the treatment.

In terms of nature of science views, between group comparison indicated that students receiving HOS instruction elucidated significantly more adequate views than students receiving curriculum-oriented instruction regarding tentative, subjective, and inferential nature of science while they did not differ significantly in terms of empirical and creative aspects of NOS right after the instructions. Within group comparison of students' pre- and post-instruction views, on the other hand, indicated that experimental group students revealed better understanding in all targeted aspects of NOS after receiving HOS instruction. Comparison group students did not show any improvement about these aspects after getting curriculum-oriented instruction, as expected. At follow-up measurements, experimental group students elucidated significantly more adequate views than students in comparison group with regard to subjective, creative and imaginative, and inferential aspects of NOS. When experimental group students' post and follow-up NOS views were compared within the group, it was found that they expressed quite similar responses to the VNOS-E items at both measurements. Moreover, comparison group students articulated quite similar responses at post and follow-up measurements too. This means that both groups retained their post views five weeks after the instructions. Overall, it can be concluded that curriculum-oriented instruction is not sufficient for developing students' nature of science views, therefore history of science should be incorporated into science curriculum to develop it. Following tables summarizes the overall results found in this study.

Table 4.89 Overall Summary of Between Group Comparisons Regarding SPST, CSCT, and TOSRA

	Time 1	Time 2	Time 3
SPST	-	-	-
CSCT	-	-	+
TOSRA	-	+	+

Note: "+" refers to statistically significant difference, in favor of experimental group;
"-" refers to statistically non-significant difference.

Table 4.90 Overall Summary of Between Group Comparisons Regarding NOS Aspects

Aspects	Time 1	Time 2	Time 3
Tentative	-	+	-
Subjective	-	+	+
Empirical	-	-	-
Creative and Imaginative	-	-	+
Inferential	-	+	+

Note: "+" refers to statistically significant difference, in favor of experimental group;
"-" refers to statistically non-significant difference.

Table 4.91 Overall Summary of Within Group Comparisons Regarding SPST, CSCT, and TOSRA

		Time 1-Time 2	Time 2-Time 3	Time 1-Time 3
SPST	Experimental	-	-	-
	Comparison	-	-	-
CSCT	Experimental	+	+	+
	Comparison	+	+	+
TOSRA	Experimental	+	-	+
	Comparison	-	-	-

Note: "+" refers to statistically significant difference;
"-" refers to statistically non-significant difference.

Table 4.92 Overall Summary of Within Group Comparisons Regarding NOS Aspects

Aspect	Comparison	Group	Naive	Transitional	Informed
Tentative	Time 1-Time 2	Experimental	↓	↔	↔
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Subjective	Time 1-Time 2	Experimental	↓	↔	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Empirical	Time 1-Time 2	Experimental	↔	↓	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Creative and Imaginative	Time 1-Time 2	Experimental	↔	↔	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔
Inferential	Time 1-Time 2	Experimental	↓	↑	↑
		Comparison	↔	↔	↔
	Time 2-Time 3	Experimental	↔	↔	↔
		Comparison	↔	↔	↔

Note: "↓" refers to statistically significant decrease;
"↔" refers to statistically non-significant change;
"↑" refers to statistically significant increase.

CHAPTER V

DISCUSSION

The main purpose of this study was to compare the relative effectiveness of history of science instruction and curriculum-oriented instruction on Grade 6 students' scientific literacy. This chapter is allocated to the discussion of the results, conclusions, related implications, limitations and recommendations for further research.

5.1 Discussion of the Results

Under this heading, experimental and comparison group students' science process skills, understanding of human circulatory system concepts, attitudes toward science, and nature of science views were discussed. During the discussion of each variable, a brief review of results were also provided.

Before the instructions SPST, CSCT, TOSRA, and VNOS-E were administered to the students in both experimental and comparison groups to determine whether two groups differed in terms of these dependent variables. One-way MANOVA result indicated that the students in experimental and comparison group did not differ regarding their pretest scores on the SPST, CSCT, and TOSRA instruments. This finding suggested that both groups had similar levels of science process skills, understanding of circulatory system concepts, and attitudes toward science before the instruction. Moreover, Pearson Chi-square Test, conducted on VNOS-E data, pointed out that there was not a substantial preexisting difference between the groups' views regarding tentative, subjective, empirical, creative and imaginative, and inferential nature of science. Thus, based on these findings revealing that groups were similar prior to the instructions, it is safe to attribute any significant results on post and follow-up measurements to the implementation of different instructional methods: history of science instruction and curriculum-oriented instruction.

During the instructions, experimental group students engaged in history of science instruction and comparison group students were instructed with curriculum-oriented instruction on the topic of circulatory system. Upon the completion of the instructions, both groups were re-administered SPST, CSCT, TOSRA, and VNOS-E as posttest. Following five weeks, both groups followed regular national science and technology curriculum. At the end of this time interval, they were again tested using same instruments to determine how much they retained their science process skills, circulatory system concepts understanding, attitudes toward science, and NOS views.

The result of Repeated-Measures MANOVA showed that two groups created substantially different profiles in terms of collective dependent variables of science process skills, understanding of circulatory system concepts, and attitudes toward science. This result implied that HOS instruction and curriculum-oriented instruction lead to different gains in terms of three core dimensions of scientific literacy with the time. In light of this result, each dependent variable was further investigated following the guidelines suggested by Tabachnick and Fidell (2012).

5.1.1 Science Process Skills

The effectiveness of two instructions was compared in terms of their effects on students' science process skills. At the outset of the study, it was hypothesized that experimental group students will score higher on science process skills than comparison group. However the results revealed that there was similar change in science process skills of the groups over time. In other words, two instructions did not give an advantage over each other in terms of improving students' science process skills. The lack of significant difference between experimental and comparison group in terms of science process skills could be attributed to two reasons: students' preexisting science process skills and nature of activities used in instructions.

First, in the present study participant's pretest SPST mean scores of experimental group were 13.02 (50%) and comparison group were 12.98 (50%) out of 26. These mean scores were not low for grade six students which mean that they already possessed moderate level of science process skills before the study. This finding was consistent with the literature investigating the Turkish elementary students' science process skills. For example, Aydinli et al. (2011) investigated the Turkish elementary school students' performance on integrated science process skills in terms of gender, grade level, socioeconomic status, the education background of mother, and the number of family members. A total of 670 students from grades six, seven, and eight participated in the study. They found that sixth grade students' performance on integrated science process skills test was 4.70 out of 12 (39%). They stated that although they expected low level performance on integrated science process skills, students' level of performance was at moderate level. Similarly, Delen and Kesercioğlu (2012) compared sixth, seventh, and eighth grade students' science process skills. They found that sixth grade students' had a means of 4.18 out of 9 (46%) in terms of preexisting performance on science process skills. Moreover, in their study, sixth and seventh grade students were taught based on current curriculum, while eight graders were taught based on the previous curriculum. They have found an increase from grade six to grade seven while a decrease from grade seven to grade eight in students' science process skills scores. Based on this result, they discussed that current science curriculum develop students' science process skills. To conclude, students in the present study had already showed a moderate level of science process skills. As a result, the development of their science process skills through history of science instruction was not found to be as effective as it is hypothesized at the beginning of the study.

Second, the insignificant difference found between the groups regarding SPST may be attributed to the nature of activities. In both groups, content specific activities (e.g. the structure of and the function of the heart) were carried out based on the activities suggested in current science and technology curriculum. As a result, students in both groups participated in the same content-specific activities, except experimental group received HOS instruction. The mean scores of experimental group (*M* = 13.94) and comparison group (*M* = 13.61) at posttest showed that engaging with the same content specific activities helped students developed their science process skills similarly in both groups when compared to the mean scores at pretest (for experimental *M* = 13.02, for comparison *M* = 12.98). The integration of HOS activities did not make discernible difference in experimental group students' science process skills. At the outset of the study, it was expected that experimental group students will develop science process skills after HOS instruction because, unlike comparison group students, they became familiar with the science process skills scientists used in the development of circulatory system knowledge by the help of historical stories, video-simulations of Harvey's experiments, and timeline of blood transfusion. It was suggested that HOS aids students to understand scientists' way of thinking (Matthews, 1994; Allchin, 1992). However, it was not likely to help students gain first-hand experience. It could not provide the students with the opportunity to be actively involved in learning process in attaining science process skills. Therefore students may not develop their science process skills significantly. The literature review showed that there is not empirical evidence supporting the assumption that HOS instruction improves students' science process skills. Although Guinta (1998) and Vincent (2010) suggested some lesson materials including historical examples and case studies to stress science process skills but they did not investigate their effect on science process skills. On the other hand research showed that the development of science process skills can be mostly achievable through inquiry-based or activity-based science instruction in which students experience hands-on activities (Riley, 1979; Turpin, 2000). Lumpe and Oliver (1991) defined hands-on science activities as “any science lab activity that allows the students to handle, manipulate or observe a scientific process” (p. 345) and emphasized that these activities differ from other instructional strategies by providing students with the opportunities to interact with the materials. Moreover science processes such as formulating research problems, planning experiments, making observations, interpreting and analyzing data, and drawing conclusions identified by The National Committee on Science Education Standards and Assessment (1994) requires an activity-based approach for science teaching. Studies that report significant improvement in science process skills generally implemented activity-based or inquiry-based programs to develop these skills (Bower & Linn, 1978; Bunterm et al., 2014; Khaperde & Pradhan, 2009; Koksal & Berberoglu, 2014; Kowasupat, Jittam, Sriwattanarothai, Ruenwongsa, & Panijpan, 2012; Shaw, 1983; Yager & Akcay, 2010). Wellman (1978) found that when third graders were engaged in direct manipulative experiences, they could develop science process skills. However, in this study students could not participate in manipulative learning experiences through history of science activities. They made some observations, collect and interpret data but these were limited. This is because of the nature of circulatory system. This topic might not provide students with such opportunities to perform hands-on activities. It is an abstract topic and it is limited in terms of conducting experiments and supplying hands-on materials. For example, although students observed the structure of the heart through dissecting the sheep heart (a mammalian heart), they could not observe its function in classrooms through naked eye. Moreover they drew models for pulmonary and systemic circulation as a group but they could not observe them in a living organism. Consequently, experimental group students could not develop science process skills as expected at the beginning of the study. Although this result revealed that HOS could not provide significant improvement on experimental group students' science process skills, it also showed that it did not interfere with the development of science process skills. Based on this result, it is recommended that the effect of HOS instruction on science process skills should also be investigated with other topics in which students can engage with experimental settings or other scientific activities derived from history of science. This may reveal a more accurate picture of the relationship between HOS instruction and development of science process skills.

5.1.2 Circulatory System Concepts

The effectiveness of history of science and curriculum-oriented instructions was compared in terms of their effects on students' understanding of circulatory system concepts. At the beginning of the study it was hypothesized that history of science instruction will lead to better gains in students' understanding of circulatory system concepts. It was found that the students in experimental group (*M* = 14.47 out of 32) and comparison group (*M* = 14.59 out of 32) had similar but inadequate knowledge of circulatory system concepts prior to the instructions. This was consistent with the literature. For example, Cardak, Dikmenli, and Saritas (2008) investigated the effectiveness of 5E learning model on sixth grade students' success of circulatory system unit. They found that the experimental and comparison group students' mean scores on circulatory system test as, out of 100, 31.68 and 30.21 respectively; which were similar but inadequate. Similar to the present study, Cardak et al. (2008) could not find significant difference in pretests. Another study conducted by Cakmak, Gurbuz, and Kaplan (2012) investigated the effectiveness of concept maps on sixth grade students understanding of circulatory system concepts. They found that experimental group students had a mean score of 10.73 out of 32 and the comparison group had a mean score of 11.78 out of 32 at pretest. They stated that students had similar and inadequate knowledge of circulatory system concepts at the outset of the study.

After history of science and curriculum-oriented instructions, the results revealed that both group students developed their understanding on circulatory system concepts (M = 24.30 for experimental; M = 23.29 for comparison). However there was not a significant difference in both groups' posttest of circulatory system concepts test. This result may be explained by the implementation of the same content-specific activities in both groups although experimental group students were engaged with the historical materials. Since both groups received the same content-specific activities, they developed their understanding of circulatory system concepts similarly. In this point, history of science did not lead to significantly higher gains compared to curriculum-oriented instruction. This can be attributed to the fact that history of science is more associated with *learning about science* rather than *learning of science*. Monk and Osborne (1997) identified history of science as learning about science. The history of science does not primarily aim to teach disciplinary knowledge rather it aims to teach how scientific knowledge was developed throughout the history. It aims to develop students’ understanding of what science is, how it works, its features, methodological activities and interaction with its cultural environment (Galili & Hazan, 2001). For example, students may realize that scientific knowledge changes as a result of new evidence, information and technological developments. This result was also consistent with the research investigating the effect of history of science instruction on students’ understanding of science concepts such as Irwin (2000), Kim (2007) and Seker (2004). Therefore it was not surprising to obtain such a result at post circulatory system concepts test.

When the groups’ follow-up test scores were compared, it was found that experimental group students' follow-up scores on CSCT (M = 22.17) were significantly higher than comparison group (M = 18.46) and eta-squared statistics indicated a large between-group effect. This result meant that HOS instruction promoted better retention of circulatory system concepts than curriculum-oriented instruction. Actually the significant difference between groups in the follow-up testing regarding understanding of circulatory system concepts was one of the important findings of the current study. This finding has important contribution to relevant literature. First, some of the previous studies found that HOS instruction did not lead to a better understanding of science concepts (e.g. Irwin, 2000; Seker, 2004). These studies generally used pretest-posttest to measure participants' learning of science concepts, ignoring follow-up measurement. However, the findings of this study provided evidence that when students engage in the same content-specific activities; it may not be possible to detect the effectiveness of HOS instruction right after the implementation. Therefore, follow-up analysis may be required to see the whole picture, because it was found that when the time passes the students in HOS group retained circulatory system science concepts better than the other group. Hence it is highly suggested that studies using history of science instruction should evaluate the effectiveness of HOS instruction longitudinally. Otherwise, evaluating the effectiveness of HOS instruction only with post-test may be misleading. In addition, this finding implied that the difference between experimental and comparison groups at follow-up test arouse from the natures of implementations and this difference had practical value in terms of retaining science concepts. This finding also provided evidence to Millar and Osborne's (1998) contention that HOS allows long-term learning of science by making scientific concepts coherent, memorable, and fruitful. During the instruction it was observed that students in HOS classes involved in classroom activities more actively. They shared their ideas with their peers and collaborated on the activities. HOS materials enabled them realize how circulatory system concepts emerged and they were more enthusiastic to share their ideas with their peers. This created a social learning environment in which students interacted with each other and constructed their own knowledge. As a result, this may lead to a better retention of circulatory system concepts. In the literature, there is not sufficient evidence in terms of investigating the effect of history of science instruction on understanding of science concepts at follow-up test. One of the few studies which evaluated the effect of history of science instruction on retention of science concepts was conducted by Kim (2007). She used a research design similar to this study as pre, post, and delayed post test. The author found no significant results in students understanding of genetic concepts at the delayed post test.

5.1.3 Attitudes Toward Science

The effectiveness of two instructions was compared in terms of their effects on students' attitudes toward science. At the beginning of the study it was hypothesized that students receiving history of science instruction will improve their attitudes toward science after instruction. The pretest scores on TOSRA between groups (M = 3.45 for experimental; M = 3.41 for comparison) showed that students in both groups were holding similar and above average attitudes toward science. This result was consistent with other studies conducted with Turkish sixth grade students. For example, Cetin and Gunay (2006) investigated the effect of constructivist learning approach on sixth grade students' attitudes toward science. At pretest, they found that the experimental and comparison group students' mean attitudes scores (M = 66.68 for experimental; M = 62.91 for comparison out of 85) were similar and above average. Similarly Senol, Bal, and Yildirim (2007) investigated the effect of cooperative learning strategy on sixth grade students' attitudes toward science. The experimental group students' mean score was 161.83 out of 225 and the comparison group had a mean score of 162.75. There was no significant difference between groups and their pre attitudes scores were above average similar to the pretest attitudes scores in the present study. Bulut, Gul

Guven and Guzel (2009) examined the sixth grade students' attitudes toward science in a descriptive and also found that their attitudes as above average (*M* = 4.09 out of 5). To conclude sixth grade students had similar attitudes toward science with a level above average before having any formal education other than curriculum oriented instruction.

Associated analysis showed that right after the instructions the mean attitudes score of the groups were significantly different than each other, in favor of experimental group. Moreover, statistically significant difference existed between experimental and comparison group five weeks after the completion of the study. This result implied that HOS instruction promoted favorable attitudes toward science better than curriculum-oriented instruction. The positive effect of HOS instruction on students' attitudes toward science was emphasized by many scholars (Carvalho & Vannucchi, 2000; .Gallagher, 1991; Kubli, 1999; Matthews, 1994; Monk & Osborne, 1997; Russell, 19981). There is also empirical evidence about positive influence of HOS on attitudes toward science which were reported in the literature (e.g. Solbes and Traver, 2003; Mamlok-Naaman, et. al, 2005). Lin, Cheng, and Chang (2010), for instance, examined the effect of history of science teaching on promoting attitudes toward science. The research team revealed that students exposed to HOS instruction develop their positive attitudes toward science better than students exposed to textbook-driven instruction. They emphasized that traditional, textbook-driven instruction introduce students with pure science concepts without including related background knowledge and this directs students to seem science as a boring activity. On the other hand, HOS makes students to perceive science vivid by allowing students to comprehend that scientists are like other people. They concluded that students have fun with science by integrating the history of it. Thus the history of science instruction is found to provide an environment in which students' could develop positive attitudes toward science. Indeed, Haladyna, Olsen, and Shaughnessy (1982) emphasized that "research should lead practitioners to develop teaching methods, materials, and educational experiences to foster positive students' attitudes" (p. 671). They underlined the impact of the learning environment and students' active involvement in learning process on students' development of favorable attitudes toward science. Matthew (1994) argued that HOS instruction may foster students' positive attitudes toward science through humanizing science because students will have a chance to be aware of scientists' life and the times of those scientists. He added that integrating historical material into classroom context have also potential to make subject matter more engaging for students. Indeed, during the instruction it was noticed that students in experimental group participated to the activities more actively than comparison group students. There were also some other research which empirically tested the impact of HOS on attitudes toward science and found positive relationship between the two. Solbes and Traver (2003), for example, designed classroom activities based on history of science in physics and chemistry for secondary school students. The experimental group was instructed with the historical approach while comparison group received traditional instruction. As a result, it was found that learning physics and chemistry through history of science improved students' attitudes toward science. Seker (2004) also found adding stories about history of scientists affected positively students' interest in science. Another study (Mamlok-Naaman et al., 2005) also supported the results of the present study. It reported that students developed positive attitudes after learning science with history and the students who did not choose science as a major showed more interest in science. To conclude the integration of history of science to circulatory system resulted in that science was humanized and an abstract topic was made more concrete, understandable and enjoyable. The interesting ideas in the history of circulatory system such as first blood transfusion from a sheep to a man, the experiments Harvey conducted, and the cultural differences contributed to the improvement in students' attitudes toward science.

5.1.4 Nature of Science

Lastly, in the present study, the effectiveness of two instructions was compared in terms of their effects on students' nature of science views. The results indicated that prior to instruction, there was not a preexisting difference between experimental and comparison group in terms of any targeted NOS aspects. While most of the students in both groups hold naïve views especially about tentative, subjective, and inferential nature of science, they articulated more adequate views regarding empirical, and creative and imaginative NOS at the outset of the study. Literature also reported similar findings (Akerson & Donnelly, 2010; Khishfe & Abd-El-Khalick, 2002; Khishfe, 2008; Quigley, Pongsanon, & Akerson, 2010). For example, while studying the effects of explicit-reflective NOS instruction on elementary students' understanding of nature of science tenets, Quigley, Pongsanon, and Akerson (2010) found that only one student (out of 19) could articulate an informed understanding of tentative NOS prior to the instruction. They also found that although half of the students could refer to creativity in describing science, no one could perceive how scientists use their creativity in doing science. They further reported that considerable percent of students elucidated adequate views on empirical NOS before the instruction. Similarly, Khishfe and Abd-El-Khalick (2002) studied with 62 sixth-grade students to investigate the relative influence of explicit-reflective instruction and implicit inquiry-oriented instruction on participants' nature of science understanding. The researcher measured students' pre- and post-instruction NOS views. In terms of pre-instruction NOS views, the authors reported that eighty-five percent of the all participants revealed a naïve view regarding tentative and inferential NOS. The researchers also found that eighty-two percent of participants demonstrated a naïve view about the role of creativity in scientific knowledge. Students preexisting naïve views may be resulted from two reasons. One of the reasons of students' naïve views before the instructions might result from science textbooks (Bell, 2004; Irez, 2009; Abd-El-Khalick, Waters & Le, 2008). For example, Abd-El-Khalick et al. 2008) examined 14 high school chemistry textbooks in terms of their accuracy, unity, and approach (explicit or implicit) to NOS. The researchers indicated that the books were insufficient for reflecting nature of science tenets. More importantly, some of the books provided messages which have a potential to foster readers' inadequate NOS views. Similar problem was also reported in Turkish context. Irez

(2009), for instance, examined five frequently used Turkish high-school textbooks for the appropriateness of underlying nature of science. He found a serious problem in terms of communicating nature of science aspects. The author reported that all of these textbooks describe science as built up of facts, instead of practice of observing the nature for producing alternative explanations. Unfortunately, corresponding serious problems were also covered in national elementary science curriculum materials in Turkey. For example, Turkish Science and Technology Teacher Guidebook for the seventh graders states that (see Appendix R-1 for the original text):

> ... If the existing studies support the hypothesis, the quality and validity of the hypothesis increases. If other hypotheses support it, then, the hypothesis becomes a theory. After a long process, if the theory becomes universal, not giving the possibility for objection, it become a scientific fact and finally, it becomes a law (MoNE, 2008, p. 9-4).

The Teacher Guidebook further claimed that (see Appendix R-2 for the original text):

> While some scientists conduct theoretical research, others concentrate on experimental studies. In addition, some others are more interested in technological designs. Regardless of these differences, all scientists follow a scientific process. First, they decide on what they are looking for; next they collect resources which support their ideas; then they make observation and conduct experiments and produce alternative solutions (MoNE, 2008, p. 9-2)

Although the above two quotations exemplify how textbooks may trigger inadequate understanding of nature science, there are also other reference which may provoke inadequate NOS views. For example, the same book describes science, among others, as "finding the truth", "to observe and to describe the facts" (p. 9-2). Similar problems were also evident in the following publications of Teacher Guidebook which may cause inadequate views regarding nature of science. For example, the Teacher Guidebook (MoNE, 2011) for grade-six level expressed that science is: "to explain facts with theories"; "to observe and to describe the facts"; and "scientific knowledge is objective in terms of moral values" (p. 9-2). All of these ideas are in conflict with the tenets of nature of science and demonstrate that textbooks may be a possible source of inadequate views among students. Another possible source of students inadequate NOS conception prior to instruction may be teacher's inadequate NOS views (Abd-El-Khalick & Lederman, 2000; Akerson, Cullen, & Hanson, 2009; Lederman & Zeidler, 1986; Lederman, 1992; Vázquez-Alonso, García-Carmona, Manassero-Mas, & Bennàssar-Roig, 2012; Wahbeh & Abd-El-Khalick, 2013). The literature provides evidence that teachers and their students held similar conception of NOS. For example, Dogan and Abd-El-Khalick (2008) investigated students and their teachers' NOS views in a representative sample consisting of 2,087 students and with 378 science teachers in Turkey. One of important findings of the survey revealed that students' NOS views were similar to those of their teachers. Similarly, Kucuk (2006) studied with 17 students and their science teacher to test the effectiveness of explicit-reflective instruction on seventh graders NOS views as well as their teacher. He found that students held certain misconception about tentative, empirical, creative and imaginative and inferential NOS prior to the study. He also found that the teacher also articulated similar misconceptions regarding tentative, empirical, and subjective nature of science at the outset of the study. To summarize, aforementioned literature suggest that textbooks and teachers may be two important sources of students' inadequate views before the instructions.

After the instructions, students in experimental group elucidated significantly more adequate views than students in comparison group regarding tentative, subjective, and inferential nature of science while they did not differ significantly in terms of empirical and creative aspects of NOS. However, within group comparison of students' pre- and post-instruction views were considered, it was found that experimental group students' understanding in all targeted aspects of NOS improved after participating in HOS instruction. Students who exposed to curriculum oriented instruction, on the other hand, fail to show any improvement about these aspects. After the instructions, majority of participants receiving HOS instruction improved their informed views about empirical, subjective, creative and imaginative, and inferential NOS. Moreover, the number of students in experimental group who elucidated naïve views regarding tentative, subjective and inferential aspects of NOS decreased significantly after HOS instruction. The percent of participants in experimental group who revealed transitional views about empirical aspect decreased after HOS instruction while transitional inferential views increased significantly as well. When the literature investigating the relationship between history of science and nature of science was examined, it was found that the results differed from study to study. For example, Abd-El-Khalick

(1998) investigated the effect of HOS on NOS views and could not find enough evidence to support that history of science instruction did enhance nature of science views. On the other hand, there is a number of studies supporting the positive influence of HOS on participants' NOS views (Howe & Rudge, 2005; Lin & Chen, 2002; Rudge & Howe, 2009; Seker & Welsh, 2006; Smith, 2010). For instance, Irwin (2000) reported that history of science instruction on atomic theory helped middle school students develop better understanding of scientific theory and tentative aspects of NOS. Another study conducted by Lin and Chen (2002) revealed that HOS instruction improved participants' understanding of NOS aspects which are the creative, subjective NOS, as well as the functions of theories. Seker and Welsh (2006) also reported the improvement in students’ ideas of scientific methods and the role of inference in the scientific process with the HOS instruction. The result of the present study supported that history of science instruction have a positive influence on developing students' nature of science views than curriculum-oriented instruction does. This finding may be explained with several factors. Firstly, each historical material was prepared in such a way that each targeted NOS aspect was aimed as an instructional goal. Also each historical material allowed students to make connection between historical material and targeted NOS aspects. These two attempts, taken together, were named as "explicit-reflective" NOS instruction in science education literature (Akerson, Abd-El-Khalick, & Lederman, 2000; Bell, Matkins, & Gansneder, 2011; Khishfe & Abd-El-Khalick, 2002; Rudge & Howe, 2009; Wahbeh, 2009). Comparison group students, on the other hand, followed curriculum-oriented activities which focus on mostly process skills by means of different activities (Berberoglu et al., 2009). When the sixth-grade science and technology curriculum is examined, it is found that there is not any objective in circulatory system which targeted any NOS aspects. Also, the examination of Teacher Guidebook (MoNE, 2011) indicated that the activities did not include explicit reference to the discussion of NOS aspects at all. Overall, curriculum-oriented instruction includes inquiry activities but it lacks of explicit-reflective elements. This approach reflects the characteristics of implicit approach which contends that by doing science, students can develop more adequate understanding of NOS (Abd-El-Khalick & Lederman, 2000; Khishfe, 2008). To sum, the instruction implemented in experimental group reflected the characteristics of explicit-reflective NOS instruction while comparison group's instruction revealed implicit NOS instruction character. The literature consistently shown that explicit-reflective instruction is more effective than implicit instruction in terms of developing nature of science views (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2000; Demirbas & Balci, 2012; Khishfe & Abd-El-Khalick, 2002; Schwartz, Lederman, & Crawford, 2004). For example Moss (2001) studied the effect of implicit instruction on high-school students' understanding of science through project-based, hands-on activities. Although implementations lasted for a full year, students' NOS understandings did not develop through engaging implicit instruction. The author recommended that throughout teaching of science, the effective way to teach NOS might be explicit instead of implicit. Khishfe and Abd-El-Khalick (2002) compared the effectiveness of implicit inquiry-oriented instruction and explicit and reflective approach on sixth graders' nature of science views. They found that an explicit and reflective inquiry-oriented approach was more effective than an implicit inquiry-oriented approach in promoting students' NOS views. They concluded that students' NOS views do not develop as a result of participating in inquiry activities without explicitly referring to the nature of science aspects. Akerson, Hanson, and Cullen (2007) also investigated the influence of explicit and reflective instruction with guided inquiry on participants' NOS views. The authors found that explicit-reflective NOS activities were effective in improving NOS views. More recently Demirbas and Balci (2012) investigated the effectiveness of explicit-reflective instruction on six-grade students' nature of science understanding. The researchers found that explicit-reflective instruction developed students' NOS views. Therefore, one of the factors which enabled the development of experimental group students' nature of science views could be attributed to explicit-reflective characteristics of the instruction. Through historical materials used in the present study, experimental group students engaged in explicit-reflective discussion of targeted NOS aspects. Students shared their ideas, questioned others thoughts, challenged with counterclaims, came up with new ideas, and provided evidence from historical material by making explicit connection between the historical material and specific NOS aspect.

Another factor which enabled experimental group students to be more competent in terms of nature of science views could be attributed to contextualized characteristics of activities used in experimental group. Clough (2006) argued that explicit-reflective instruction may be both decontextualized and contextualized.

According to Clough, contextualized NOS instruction differ from decontextualized NOS instruction in that it explicitly and reflectively focuses on targeted NOS aspects by incorporating specific science content. It also bridges the gap between science and society by exhibiting the human-side of science (Clough, 2006). Other researchers also suggested that NOS should be embedded into science content (e.g. Brickhouse, Dagher, Letts IV, & Shipman, 2000; Kruse, 2010), otherwise both students and their teacher may perceive NOS as extraneous which is apart from science content (Bell et al., 2011). In this study, history of science was used as a means to contextualize NOS tenets in circulatory system topic. For example, the first content-specific activity in circulatory system topic was the structure and the function of the heart. Before this activity, experimental group students were engaged in the first historical activity which illustrated how the human heart was conceptualized differently by different scientists through emphasizing tentative and subjective NOS aspects. In other words, history of science was embedded into circulatory system for students' better comprehension of NOS aspects. Instead of history of science, if a generic activity (e.g. black box), which is decontextualized in nature, was used to emphasize NOS aspects students may not develop deeper understanding of NOS (Clough, 2006).

At follow-up measurements experimental group students elucidated significantly more adequate views than students in comparison group as well. When experimental group students’ post and follow-up NOS views were compared within the group, it was found that they expressed very similar responses to the VNOS-E items at both measurements. Moreover, comparison group students articulated quite similar responses at post and follow-up measurements too. This result showed consistency with other research in the literature. For example, Kim (2007) investigated the effects of history of science instruction on learning of genetic concepts and nature of science. In terms of NOS, she found that comparison group students who followed regular instruction did not differ between pretest, posttest, and delayed posttest. However, students in experimental group who engaged in historical material developed their NOS views right after the instruction and they retained their developed views. Hence, it can be concluded that curriculum-oriented instruction is not sufficient for developing students' nature of science views, therefore history of science should be incorporated into science curriculum to develop it.

Overall, the findings of the current study revealed that history of science instruction improves students' retention of science concepts, attitudes toward science, and nature of science views better than curriculum oriented instruction. In terms of science process skills, although HOS instruction did not lead to a higher gains, it also did not result in any retreat about science process skills.

5.2 Implications

The current study investigated the comparative effectiveness of history of science instruction and curriculum-oriented instruction on sixth-grade students' science process skills, understanding of circulatory system concepts, attitudes toward science, and nature of science views. It was found that history of science instruction was more effective than curriculum-oriented instruction on the development of students' attitudes toward science, retention of circulatory system concepts as well as nature of science views. However, experimental group students did not indicate higher gains regarding science process skills than comparison group. Based on the results, this study has a number of implications.

First, it was found that history of science instruction neither favored nor disfavored the development of science process skills over curriculum-oriented instruction. This result, combined with the results reported in previous studies, implied that developing science process skills, especially for lower-grade students, require more experiential learning (i.e. allowing students to physically interact with objects) in which students can use more senses like touching and seeing. It is recommended that apart from making demonstrations and providing students with opportunities to watch videos, science teachers should also allow students to engage in activities and perform experiments in which they can experience a variety of science process skills. For example, students may be allowed to re-create the original experiment of an ancient scientist or setup of a historical investigation to let them be more competent in terms of science process skills.

Second, the result indicated that although two groups did not differ right after the instructions in terms of understanding circulatory system concepts, there was a significant difference between the groups at follow-up measurement in favor of experimental group. This result provided evidence to support the claim that incorporating history of science into classroom environment promotes better retention of science concepts. Moreover, the current study demonstrates that the use of follow-up measurement, in combination with pre- and post-instruction measurements, are effective for determining the way students retain science concepts. Therefore the assessment of the effect of history of science instruction on students' understanding of science concepts should be done with follow-up measurements as well as post-test so that the effectiveness of HOS instruction may begin to be discernible with the time. This will prevent to report an incomplete result which may discredit the use of history of science instruction. Hence, science education researchers, who study the effectiveness of history of science instruction on students understanding of science concepts, are highly recommended to use follow-up measurements.

Third, the result of the present study also demonstrated that history of science instruction is more efficient than curriculum-oriented instruction in terms of developing students' attitudes toward science. Based on this result, it is possible to conclude that history of science instruction, in which students learn about how science works while learning science, lead to a positive attitudes toward science. Therefore, it is recommended to curriculum developers and teachers that history of science instruction should be incorporated into science and technology curriculum in order to develop favorable attitudes toward science. Besides, due to the fact that students' attitudes toward science shapes at their early ages and last for a long time, it is also suggested that history of science instruction should be incorporated into curriculum at the earlier stages of schooling. Consequently, students may be predisposed to maintain their positive attitudes at subsequent grades.

Forth, the result of this study provide empirical evidence to deduce that history of science instruction is an important context in which students can develop more adequate nature of science views. While students in comparison group articulated and preserved their naive views about certain aspect of NOS during the course of the study, experimental group students expressed more adequate views after the instruction and retained their adequate views. This result implied that the current science and technology curriculum, although aiming to develop NOS views, is not sufficient for improving NOS views. Moreover, curriculum materials might be among the potential sources of students' naive NOS views. On the other hand, HOS improved students' NOS views through contextualized explicit-reflective NOS approach. This result also implied that HOS should be an integral part of science curriculum and it is recommended for teachers to discuss NOS aspects explicitly and reflectively in science classrooms.

The overall picture emerging from this study is that, history of science instruction can serve as an appropriate instruction to develop students' scientific literacy through fostering its core elements. The findings of this study provided evidence that current science and technology curriculum is devoid of historical materials. Students, especially in lower grades, need to be provided ample of historical materials to improve their scientific literacy. Therefore it is recommended to curriculum developers that history of science should be incorporated into science and technology curriculum implemented in Turkey. They need to develop materials which incorporate historical materials to science teaching. Also, curriculum developers should provide teachers with historical materials and diverse resources about it.

Moreover, the findings of this study have some implications for teacher education program as well as in-service training program. As mentioned in the methodology chapter, the researcher implemented the instruction in experimental group because, besides other factors, the teacher in this study indicated that he could not able to succeed in history of science instruction due to his incompetence about it. One of the important factors of teachers inadequacy in implementing history of science instruction may results from teacher education program and in-service training program. Neither teacher education program nor in-service training program offer history of science courses to pre-service and in-service science teachers formally. For that reason, it is advocated that teacher education program should offer at least one must course regarding history of science instruction. In this course, a combination of different historical materials from physics, chemistry, and biology should be developed and offered to pre-service science teacher to prepare them for history of science instruction. This course should also provide preservice science teachers with the opportunity of pedagogical practices, such as writing objectives considering historical materials, preparing lessons plan by incorporating historical material into content-specific activities, and teaching with historical materials. These pedagogical practices will prepare future science teachers equipped with required skills for the implementation of historical materials into classroom environment. Moreover, in-service training program should offers similar training for in-service teachers. Above all, science teachers should use history of science in their classrooms more actively.

5.3 Limitations and Recommendations

The present study have some limitations. Taken those limitations into consideration may strengthen the validity of future research. First of all, the sample of the study was drawn from four intact classes because there was no chance to select participants randomly. Although the students were coming from comparable backgrounds, which was also ensured with the related descriptive data (see Table 3.2), still due to chance factor there may be some hidden systematic difference (such as, academic achievement levels, motivation level) between the groups which may influence the findings. Choosing the sample randomly in future research will increase the representativeness of the population which in turn increase the generalization of the result to the target population. Additionally, if this study can be replicated with larger sample size, the generalizability can also increase.

Second, historical materials developed in this study were limited to “human circulatory system” unit in science and technology curriculum. Therefore, the effect of history of science instruction was assessed in human circulatory system in the current study. The investigation of the effect of history of science instruction in other topics may provide evidence about the transferability of the effect of HOS instruction to other settings in future research.

Third, the participants of the present study was chosen from sixth-grade students and they were coming from families of middle to high socio-economic status (SES). The probability of having more books is higher for those groups than students coming from low SES. Having more books also means likelihood of reading more historical stories. Therefore the result may not reflect the exact situation if generalized to students coming from low SES. In order to draw more complete picture about the effect of history of science instruction on related variables, the study may be replicated with different grade levels and different sample coming from low socio-economic status.

Fourth, testing threat was also among possible limitations of this study due to the repeated administration of the instruments. Throughout this study, aforementioned instruments used at pretest, posttest, and follow-up test. Some students may be alert in remembering before-used instruments. Therefore, additional data may be collected from the sample in following semesters using alternative instruments.

Fifth, as mentioned in methodology chapter, while experimental group students was engaging in historical materials, comparison group students engaged in activities different than circulatory system topic in order to balance the time between the groups. Although this application allowed researcher not only to balance time, but also to administer the tests to the groups at parallel time intervals; this might lead comparison group students to be disadvantageous in terms of science content knowledge. In future studies participating another group to the study and eliminating unrelated topic for them may be helpful for more precise result.

Last, the activities in experimental group was introduced by the researcher while comparison group students was taught by their science teacher. Although, various efforts was made to equate the groups as explained in the Methodology chapter, there might still have some effect on the results. Therefore to overcome this, one classroom may be added to the design and instructed by their science teacher who is trained about history of science instruction.

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APPENDICES

APPENDIX A

A. SCIENCE PROCESS SKILLS TEST (SPST)

(BİLİMSEL SÜREÇ BECERİLERİ TESTİ)

1) Arabaların verimliliğini inceleyen bir araştırma yapılmaktadır. Test edilen hipotez, benzine katılan katkı maddesinin arabaların verimliliğini arttırdığı yolundadır. Aynı tip beş arabaya, aynı miktarda benzin ve farklı miktarlarda katkı maddesi konulur. Arabalar benzinleri bitinceye kadar aynı yol boyunca giderler. Daha sonra her arabanın aldığı mesafe kaydedilir. Bu çalışmada arabaların verimliliği sizce nasıl ölçülür?

- **a.** Arabaların benzinleri bitinceye kadar geçen süre ile.
- **b.** Her arabanın gittiği mesafe ile.
- **c.** Kullanılan benzin miktarı ile.
- **d.** Kullanılan katkı maddesinin miktarı ile.

2) Bir araba üreticisi daha ekonomik arabalar yapmak istemektedir. Araştırmacılar arabanın litre başına alabileceği mesafeyi etkileyebilecek değişkenleri araştırmaktadırlar. Sizce aşağıdaki değişkenlerden hangisi arabanın litre başına alabileceği mesafeyi etkileyebilir?

- **a.** Arabanın ağırlığı.
- **b.** Motorun hacmi.
- **c.** Arabanın rengi
- **d.** a ve b.

3) Bir polis şefi, araç kullanma hızının azaltılması ile uğraşmaktadır. Araç kullanma hızını etkileyebilecek bazı faktörler olduğunu düşünmektedir. Sürücülerin ne kadar hızlı araba kullandıklarını sizce aşağıdaki hipotezlerin hangisiyle test edilebilir?

- **a.** Daha genç sürücülerin daha hızlı araba kullanma olasılığı yüksektir.
- **b.** Kaza yapan arabalar ne kadar büyükse, içindeki insanların yaralanma olasılığı o kadar azdır.
- **c.** Yollarda ne kadar çok polis ekibi olursa, kaza sayısı o kadar az olur.
- **d.** Arabalar eskidikçe kaza yapma olasılıkları artar.

4) Bir fen dersinde, tekerlek genişliğinin tekerleğin daha kolay yuvarlanması üzerine etkisi araştırılmaktadır. Bir oyuncak arabaya geniş tekerlekler takılır, önce bir rampadan (eğik düzlem) aşağı bırakılır ve daha sonra düz bir zemin üzerinde gitmesi sağlanır. Deney, aynı arabaya daha dar tekerlekler takılarak tekrarlanır. Hangi tip tekerleğin daha kolay yuvarlandığı sizce nasıl ölçülür?

- **a.** Her deneyde arabanın gittiği toplam mesafe ölçülür.
- **b.** Rampanın (eğik düzlem) eğim açısı ölçülür.
- **c.** Her iki deneyde kullanılan tekerlek tiplerinin genişlikleri ölçülür.
- **d.** Her iki deneyin sonunda arabanın ağırlıkları ölçülür.

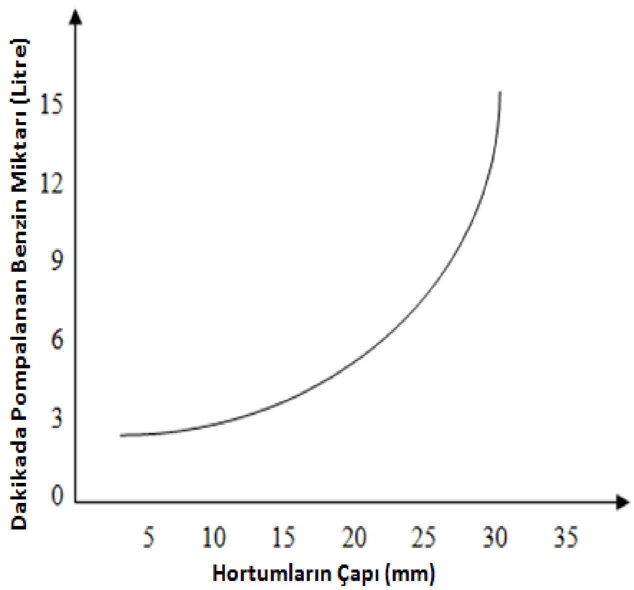
5) Ahmet basketbol topunun içindeki hava arttıkça, topun daha yükseğe sıçrayacağını düşünmektedir.

Bu hipotezi araştırmak için, birkaç basketbol topu alır ve içlerine farklı miktarda hava pompalar. Sizce Ahmet hipotezini nasıl test etmelidir?

- **a.** Topları aynı yükseklikten fakat değişik hızlarla yere vurur.
- **b.** İçlerinde farklı miktarlarda hava olan topları, aynı yükseklikten yere bırakır.
- **c.** İçlerinde aynı miktarlardaki hava olan topları, zeminle farklı açılardan yere vurur.
- **d.** İçlerinde aynı miktarlarda hava olan topları, farklı yüksekliklerden yere bırakır.

6) Bir tankerden benzin almak için farklı genişlikte 5 hortum kullanılmaktadır. Her hortum için aynı pompa kullanılır. Yapılan çalışma sonunda elde edilen bulgular aşağıdaki grafikle gösterilmiştir.

Size göre aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi açıklamaktadır?



a. Hortum genişledikçe dakikada pompalanan benzin miktarı da artar.

b. Dakikada pompalanan benzin miktarı arttıkça, daha fazla zaman gerekir.

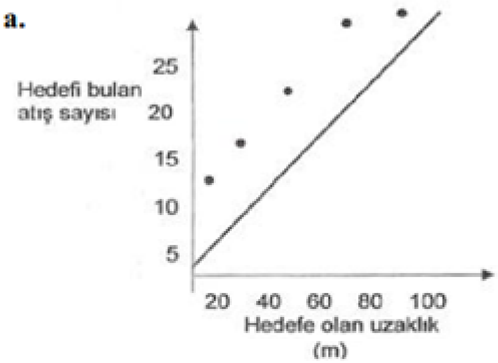
c. Hortum daraldıkça dakikada pompalanan benzin miktarı da artar.

d. Pompalanan benzin miktarı azaldıkça, hortum genişler.

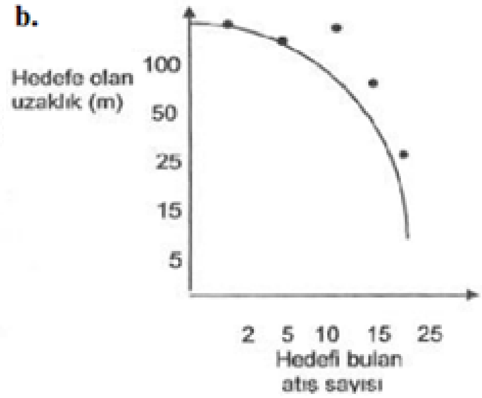
7) Bir hedefe çeşitli mesafelerden 25 er atış yapılır. Her mesafeden yapılan 25 atıştan hedefe isabet edenler aşağıdaki tabloda gösterilmiştir. Bu tabloya göre aşağıdaki grafiklerden hangisi çizilmelidir?

Mesafe (m)	Hedefe vuran atış sayısı
5	25
15	10
25	10
50	5
100	2

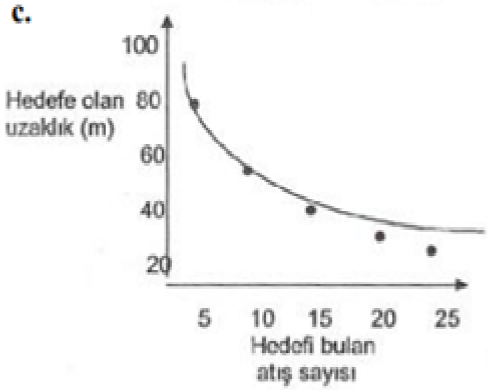
a.



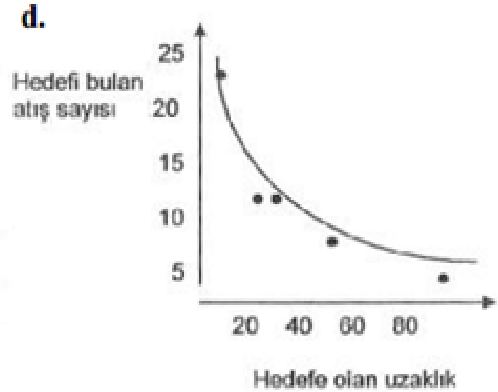
b.



c.



d.



8., 9., 10. ve 11. soruları aşağıdaki bilgiye göre cevaplayınız.

Ayşe, güneşin karaları ve denizleri aynı derecede ısıtıp ısıtmadığını merak etmektedir. Bir araştırma yapmaya karar verir ve aynı büyüklükte iki kova alır. Bunlardan birini toprakla, diğerini de su ile doldurur ve aynı miktarda güneş ışığı alacak şekilde bir yere koyar. Günün 8.00-18.00 saatleri arasında, her saat başı sıcaklıklarını ölçer.

8) Sizce araştırmada aşağıdaki hipotezlerden hangisi test edilmiştir?

a. Toprak ve su ne kadar çok güneş ışığı alırlarsa, o kadar ısınırlar.

b. Toprak ve su güneş altında ne kadar fazla kalırlarsa, o kadar çok ısınırlar.

c. Güneş farklı maddeleri farklı derecelerde ısıtır.

d. Günün farklı saatlerinde güneşin yaydığı ısı da farklı olur.

9) Sizce araştırmada aşağıdaki değişkenlerden hangisi sabit tutulmuştur?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

10) Sizce araştırmada ölçülen değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

11) Sizce araştırmada değiştirilen değişken hangisidir?

a. Kovadaki suyun cinsi.

b. Toprak ve suyun sıcaklığı.

c. Kovalara koyulan maddenin türü.

d. Her bir kovanın güneş altında kalma süresi.

<u>12., 13., 14. ve 15. soruları aşağıdaki bilgiye göre cevaplayınız.</u>

Murat, suyun sıcaklığının, su içinde çözünebilecek şeker miktarını etkileyip etkilemediğini araştırmak ister. Birbirinin aynı dört bardağın her birine 50 mililitre su koyar. Bardaklardan birisine 0 ^{0}C de, diğerine de sırayla 50 ^{0}C, 75 ^{0}C ve 95 ^{0}C sıcaklıkta su koyar. Daha sonra her bir bardağa çözünebileceği kadar şeker koyar ve karıştırır.

12) Bu araştırmada sizce test edilen hipotez hangisi olabilir?

- **a.** Şeker ne kadar çok suya karıştırılırsa o kadar çok çözünür.
- **b.** Ne kadar çok şeker çözünürse, su o kadar tatlı olur.
- **c.** Sıcaklık ne kadar yüksek olursa, çözünen şekerin miktarı da o kadar fazla olur.
- **d.** Kullanılan suyun miktarı arttıkça sıcaklığı da artar.

13) Bu araştırmada sizce sabit tutulan değişken hangisidir?

- **a.** Her bardaktaki çözünen şeker miktarı.
- **b.** Her bardağa konulan su miktarı.
- **c.** Bardakların sayısı.
- **d.** Suyun sıcaklığı.

14) Sizce araştırmanın ölçülen değişkeni hangisidir?

- **a.** Her bardaktaki çözünen şeker miktarı.
- **b.** Her bardağa konulan su miktarı.
- **c.** Bardakların sayısı.
- **d.** Suyun sıcaklığı.

15) Sizce araştırmadaki değiştirilen değişken hangisidir?

- **a.** Her bardaktaki çözünen şeker miktarı.
- **b.** Her bardağa konulan su miktarı.
- **c.** Bardakların sayısı.
- **d.** Suyun sıcaklığı.

16) Bir bahçıvan domateslerinin çabuk filizlenmesini istemektedir. Değişik birkaç alana domates tohumu eker. Hipotezi, tohumlar ne kadar çok sulanırsa, o kadar çabuk filizleneceğidir. Sizce bu hipotezi nasıl test eder?

- **a.** Farklı miktarlarda sulanan tohumların kaç günde filizleneceğine bakar.
- **b.** Her sulamadan bir gün sonra domates bitkisinin boyunu ölçer.
- **c.** Farklı alanlardaki bitkilere verilen su miktarını ölçer.
- **d.** Her alana ektiği tohum sayısına bakar.

17) Ahmet, buz parçacıklarının erime süresini etkileyen faktörleri merak etmektedir. Buz parçalarının büyüklüğü, odanın sıcaklığı ve buz parçalarının şekli gibi faktörlerin erime süresini etkileyebileceğini düşünür. Daha sonra şu hipotezi sınamaya karar verir. Buz parçalarının şekli erime süresini etkiler. Sizce Ahmet bu hipotezi sınamak için aşağıdaki deney tasarımlarının hangisini uygulamalıdır?

- **a.** Her biri farklı şekil ve ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta, benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
- **b.** Her biri aynı şekilde fakat farklı ağırlıkta beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
- **c.** Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar aynı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.
- **d.** Her biri aynı ağırlıkta fakat farklı şekillerde beş buz parçası alınır. Bunlar farklı sıcaklıkta benzer beş kabın içine ayrı ayrı konur ve erime süreleri izlenir.

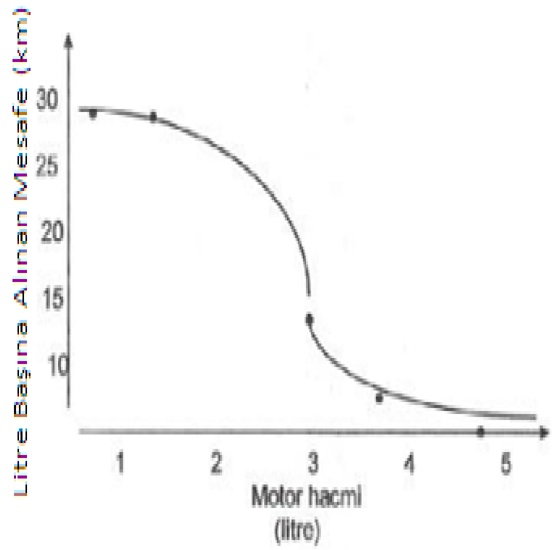
18) Bir biyolog şu hipotezi test etmek ister; Farelere ne kadar çok vitamin verilirse o kadar hızlı büyürler. Biyolog farelerin büyüme hızını sizce nasıl ölçebilir?

- **a.** Farelerin hızını ölçer.
- **b.** Farelerin, günlük uyumadan durabildikleri süreyi ölçer.
- **c.** Her gün fareleri tartar.
- **d.** Her gün farelerin yiyeceği vitaminleri tartar.

19) Öğrenciler, şekerin suda çözünme süresini etkileyebilecek değişkenleri düşünmektedirler. Suyun sıcaklığını, şekerin ve suyun miktarlarını değişken olarak saptarlar. Öğrenciler, şekerin suda çözünme süresini sizce aşağıdaki hipotezlerden hangisiyle sınayabilir?

- **a.** Daha fazla şekeri çözmek için daha fazla su gereklidir.
- **b.** Su soğudukça, şekeri çözebilmek için daha fazla karıştırmak gerekir.
- **c.** Su ne kadar sıcaksa, o kadar çok şeker çözünecektir.
- **d.** Su ısındıkça şeker daha uzun sürede çözünür.

20) Bir araştırma grubu, değişik hacimli motorları olan arabaların verimliliğini ölçer. Elde edilen sonuçların grafiği aşağıdaki gibidir:
Sizce aşağıdakilerden hangisi değişkenler arasındaki ilişkiyi gösterir?



a. Motor ne kadar büyükse, bir litre benzinle gidilen mesafe de o kadar uzun olur.

b. Bir litre benzinle gidilen mesafe ne kadar az olursa, arabanın motoru o kadar küçük demektir.

c. Motor küçüldükçe, arabanın bir litre benzinle gidebileceği mesafe artar.

d. Bir litre benzinle gidilen mesafe ne kadar uzun olursa, arabanın motoru o kadar büyük demektir.

<u>21., 22., 23. ve 24. soruları aşağıdaki bilgiye göre cevaplayınız.</u>

Toprağa karıştırılan yaprakların domates üretimine etkisi araştırılmaktadır. Araştırmada dört büyük saksıya aynı miktarda ve tipte toprak konulmuştur. Fakat birinci saksıdaki toprağa 15 kg., ikinciye 10 kg., üçüncüye ise 5 kg. çürümüş yaprak karıştırılmıştır. Dördüncü saksıdaki toprağa ise hiç çürümüş yaprak karıştırılmamıştır. Daha sonra bu saksılara domates ekilmiştir. Bütün saksılar güneşe konmuş ve aynı miktarda sulanmıştır. Her saksıdan elde edilen domates tartılmış ve kaydedilmiştir.

21) Bu araştırmada sizce test edilen hipotez hangisidir?

- **a.** Bitkiler güneşten ne kadar çok ışık alırlarsa, o kadar fazla domates verirler.
- **b.** Saksılar ne kadar büyük olursa, karıştırılan yaprak miktarı o kadar fazla olur.
- **c.** Saksılar ne kadar çok sulanırsa, içlerindeki yapraklar o kadar çabuk çürür.
- **d.** Toprağa ne kadar çok çürük yaprak karıştırılırsa, o kadar fazla domates elde edilir.

22) Sizce bu araştırmada sabit tutulan değişken hangisidir?

- **a.** Her saksıdan elde edilen domates miktarı.
- **b.** Saksılara karıştırılan yaprak miktarı.
- **c.** Saksılardaki toprak miktarı.
- **d.** Çürümüş yaprak karıştırılan saksı sayısı.

23) Sizce araştırmada ölçülen değişken hangisidir?

- **a.** Her saksıdan elde edilen domates miktarı.
- **b.** Saksılara karıştırılan yaprak miktarı.
- **c.** Saksılardaki toprak miktarı.
- **d.** Çürümüş yaprak karıştırılan saksı sayısı.

24) Sizce araştırmada değiştirilen değişken hangisidir?

- **a.** Her saksıdan elde edilen domates miktarı.
- **b.** Saksılara karıştırılan yaprak miktarı.
- **c.** Saksılardaki toprak miktarı.
- **d.** Çürümüş yaprak karıştırılan saksı sayısı.

25) Sibel, akvaryumdaki balıkların bazen çok hareketli bazen ise durgun olduklarını gözler. Balıkların hareketliliğini etkileyen faktörleri merak eder. Sizce balıkların hareketliliğini etkileyen faktörleri hangi hipotezle sınayabilir?

- **a.** Balıklara ne kadar çok yem verilirse, o kadar çok yeme ihtiyaçları vardır.
- **b.** Balıklar ne kadar hareketli olursa o kadar çok yeme ihtiyaçları vardır.
- **c.** Su da ne kadar çok oksijen varsa, balıklar o kadar iri olur.
- **d.** Akvaryum ne kadar çok ışık alırsa, balıklar o kadar hareketli olur.

26) Murat Bey'in evinde birçok elektrikli alet vardır. Fazla gelen elektrik faturaları dikkatini çeker.

Kullanılan elektrik miktarını etkileyen faktörleri araştırmaya karar verir. Sizce aşağıdaki değişkenlerden hangisi kullanılan elektrik enerjisi miktarını etkileyebilir?

- **a.** TV nin açık kaldığı süre.
- **b.** Elektrik sayacının yeri.
- **c.** Çamaşır makinesinin kullanma sıklığı.
- **d.** a. ve c.

APPENDIX B

B. CIRCULATORY SYSTEM CONCEPTS TEST (CSCT)

(DOLAŞIM SİSTEMİ KAVRAM TESTİ)

1. Dolaşım sisteminin görevleriyle ilgili verilen bilgilerden hangileri doğrudur?

I. Hücrelerin ihtiyaç duyduğu besin maddelerini hücrelere iletir

II. Hücrelerin ihtiyaç duyduğu oksijeni hücrelere taşır.

III. Hücrelerde oluşan atık maddeleri hücrelerden uzaklaştırır

A. I ve II **B**. I ve III **C**. II ve III **D**. I, II ve III

2. Ali, insan vücudundaki yapıları dolaşım sistemini oluşturacak şekilde sınıflandırmıştır. Ali'nin yaptığı sınıflandırma hangi seçenekte verilmiştir?

A. Damarlar-Kalp-Kan

B. Damarlar-Kalp-Mide

C. Damarlar-Kan-Mide

D. Kalp-Kan-Mide

3. Kalbin dış yapısında bulunan damarların görevi nedir?

A. Kalbi besler.

B. Kulakçıkların kasılmasını sağlar.

C. Karıncıkların kasılmasını sağlar.

D. Kalbin mikroplara karşı savunmasını sağlar.

4. İnsan kalbi kaç odacıktan oluşur?

A. 1 **B**. 2 **C**. 3 **D**. 4

5. Kalbin yapısını inceleyen Arda karıncıkların kulakçıklara göre daha kaslı yapıda olduğunu gözlemler. Bu gözlemine dayanarak Arda bu durumla ilgili hangi çıkarımı yapabilir?

A. Karıncıklar kulakçıklardan daha fazla sayıda atım yapar.

B. Karıncıklar kulakçıklara göre daha güçlü pompalama yapar.

C. Karıncıklar vücuttan gelen kanı kulakçıklara pompalar.

D. Karıncıkların hacmi kulakçıklardan büyüktür.

6. Aşağıda verilen tablodaki bilgilere dayanarak kalple ilgili hangi genelleme yapılabilir?

Balık Kalbi	**Kurbağa Kalbi**	**Koyun Kalbi**
İki odacıklıdır.	Üç odacıklıdır.	Dört odacıklıdır.

A. Kalp, dolaşım sisteminin merkez organıdır.

B. Her canlının kalbi aynı yapıya sahip değildir.

C. Kalp karıncık ve kulakçıklardan oluşur.

D. Kalp kanın vücuda pompalanmasını sağlar.

7. Kanı oluşturan yapılardan hangileri hücresel özellik gösterir?

A. Alyuvar, Kan Plazması, Kan Pulcukları

B. Alyuvar, Kan Pulcukları, Akyuvar

C. Kan Plazması, Kan Pulcukları, Akyuvar

D. Alyuvar, Kan Plazması, Akyuvar

8. Bir biyolog, koyun kalbinin bölümleri arasındaki özel kapakçıkların görevleriyle ilgili aşağıdaki bulguları not etmiştir.

Olay	**Sonuç**
Kulakçıklar kasılır.	Kulakçıklardaki kan karıncıklara geçer.
Karıncıklar kasılır.	Kan kulakçıklara geri dönmez; fakat aort ve akciğer atardamarı yoluyla kalpten uzaklaşır.

Bu notlara bağlı olarak araştırmacı hangi sonuca ulaşamaz?

A. Kapakçıklar kalp kasılmasını başlatır.

B. Kapakçıklar, kulakçıklar kasıldığında kanın karıncıklara geçişine izin verir.

C. Kapakçıklar, karıncıklar kasıldığında kanın kulakçıklara dönmesini engeller.

D. Kapakçıklar, kulakçıklar ile karıncıklar arasında yer alır.

9. Canlı hayvanlar üzerine araştırma yapan bir bilim insanı, canlı bir köpeğin kalbi üzerinde aşağıdaki işlemleri yapıyor ve gözlemlerini not ediyor.

İşlem	**Gözlem**
- Kalp yakınlarındaki **X** damarını pens ile sıkıp damardaki kan akışını bir süreliğine durduruyor.	Gözlem 1: Bu damarın kalp ile sıkılan kısmı arası şişiyor. Gözlem 2: Kalp büyüyor

Gözlemlerine dayanarak bu bilim insanı X damarıyla ilgili hangi sonuca varamaz?

A. X damarı kalbin karıncığından çıkmaktadır.

B. X damarı, kanı kalpten vücuda taşıyan bir damardır.

C. X damarı, kalbin sağ kısmından çıkıyorsa akciğere bağlanmaktadır.

D. X damarı ya alt ya da üst ana toplardamardır.

10., 11., 12. ve 13. soruları aşağıdaki bilgiye göre cevaplayınız.

"Bir grup öğrenci kalp atım hızını etkileyen faktörlerle ilgili çalışma yapmaktadır. Gruptan aynı yaş ve kiloda üç kişi seçiliyor. Birincinin dinlenme konumunda, ikincinin on dakika koşu yaptırıldıktan sonra, üçüncünün yirmi dakika koşu yaptırıldıktan sonra bir dakikadaki kalp atım sayıları ölçülüyor."

10. Bu çalışmada öğrencilerin test ettiği hipotez hangisidir?

- **A.** Yaş arttıkça kalp atım hızı artmaktadır.
- **B.** Kilo arttıkça kalp atım hızı artmaktadır.
- **C.** Egzersiz süresi arttıkça kalp atım hızı artmaktadır.
- **D.** Her kişinin kendine özgü kalp atım hızı vardır.

11. Bu çalışmada hangi değişkenler sabit tutulmuştur?

- **A.** Egzersiz süresi - cinsiyet
- **B.** Yaş - kilo
- **C.** Kalp atım hızı - egzersiz süresi
- **D.** Cinsiyet - yaş

12. Bu çalışmadaki bağımlı değişken hangisidir?

- **A.** Egzersiz süresi
- **B.** Egzersiz yapan kişilerin yaşları
- **C.** Kalp atım hızı
- **D.** Egzersiz yapan kişilerin cinsiyetleri

13. Bu çalışmadaki bağımsız değişken hangisidir?

- **A.** Egzersiz süresi
- **B.** Egzersiz yapan kişilerin yaşları
- **C.** Kalp atım hızı
- **D.** Egzersiz yapan kişilerin cinsiyetleri

14. Kalbin kulakçıkları gevşediğinde aşağıdakilerden hangisi meydana gelir?

- **A.** Akciğerden ve vücuttan gelen kan kulakçıklara dolar.
- **B.** Karıncıklar da aynı anda gevşer.
- **C.** Kulakçıklar kanı karıncıklara pompalar.
- **D.** Karıncıklar kanı kulakçıklara pompalar.

15. Dolaşım sisteminde kanın vücutta dolaşmasını sağlayan damarlar kaç çeşittir?

A. 2 **B.** 3 **C.** 4 **D.** 5

16. Damarlarla ilgili aşağıdakilerden hangisi **yanlıştır**?

- **A.** Atardamarlar, kanı kalpten vücuda taşıyan damarlardır.
- **B.** Akciğer atardamarı dışındaki atardamarlar oksijence fakir kan taşır.
- **C.** Toplardamarlar, kanı kalbe getiren damarlardır.
- **D.** Akciğer toplardamarı oksijence zengin kan taşır.

17. Kılcal damarlarla ilgili aşağıdaki ifadelerden hangisi **yanlıştır**?

- **A.** Atardamarlarla toplardamarlar arasında yer alır.
- **B.** Geniş bir yüzey oluşturacak şekilde dallanmıştır.
- **C.** Vücuttaki en geniş ikinci damardır.
- **D.** Kan ile dokular arasında madde alışverişinin yapıldığı yerdir.

18. Damarların görevleriyle ilgili hangi seçenekteki eşleştirme doğrudur?

	Akciğer Atardamarı	**Aort**	**Akciğer Toplardamarı**
A.	Akciğerlere oksijence fakir kan taşır.	Akciğerlerde temizlenen kanı kalbe getirir.	Oksijence zengin kanın vücuda taşınmasını sağlar
B.	Akciğerlerde temizlenen kanı kalbe getirir.	Oksijence zengin kanın vücuda taşınmasını sağlar	Akciğerlere oksijence fakir kan taşır.
C.	Oksijence zengin kanın vücuda taşınmasını sağlar	Akciğerlerde temizlenen kanı kalbe getirir.	Akciğerlere oksijence fakir kan taşır.
D.	Akciğerlere oksijence fakir kan taşır.	Oksijence zengin kanın vücuda taşınmasını sağlar	Akciğerlerde temizlenen kanı kalbe getirir.

19. Dr. Ayşe kan tahlilini incelediği bir kişinin kanındaki akyuvar sayısını normalin üzerinde olduğunu saptamıştır. Bu kişinin durumuyla ilgili Dr. Ayşe'nin yapacağı çıkarım hangisi olabilir?

A. Bu kişi tahlil öncesi spor yapmıştır. Kandaki karbondioksiti daha kolay uzaklaştırabilmek için kanındaki akyuvar sayısı artmıştır.

B. Bu kişinin vücuduna mikrop girmiştir. Bu mikroplarla savaşabilmek için kanındaki akyuvar sayısı artmıştır.

C. Bu kişi yayla gibi yüksek rakımlı bir yerde yaşamaktadır. Bu yerlerdeki oksijen azlığından dolayı yeterli oksijeni taşıyabilmek için kanındaki akyuvar sayısı artmıştır.

D. Bu kişi aşırı derecede sigara tüketmektedir. Kan hücrelerinin oksijen temin etmesi yetersizliğine bağlı olarak kanındaki akyuvar sayısı artmıştır.

20. Bir diyetisyen öğünlere kırmızı et takviyesinin alyuvar sayısı üzerindeki etkisini araştırmak istemektedir. Diyetisyen kanında alyuvar sayısı normalden az olan aynı cinsiyetten dört kişi seçer. Bu kişilere aynı öğünlerde aynı miktarda diğer gıdalardan verip yalnızca aldıkları kırmızı et miktarlarını değiştirir. Diyetisyen çalışma sonunda bütün deneklerin kanındaki alyuvar artışını kaydeder.

Bu çalışmada diyetisyen kırmızı etin alyuvar üzerindeki etkisini nasıl ölçmüştür?

A. Alınan kırmızı et miktarlarıyla

B. Et dışında alınan diğer gıdaların miktarlarıyla

C. Araştırmaya katılan kişi sayısıyla

D. Kandaki alyuvar sayılarındaki artışla

21. I- Kanın pıhtılaşmasını sağlayan hücrelere kan pulcukları adı verilir.

II-Kan hücrelerinin içinde bulundukları sıvı kan plazmasıdır.

Kanın yapısıyla ilgili verilen ifadeler için ne söylenebilir?

A. Her ikisi de doğrudur.

B. I doğru, II yanlıştır.

C. I yanlış, II doğrudur.

D. Her ikisi de yanlıştır.

22. Kan gruplarıyla ilgili aşağıdaki ifadelerden hangisi **yanlıştır**?

A. En uygun kan alışverişi aynı kan grupları arasında gerçekleşir.

B. ABO sisteminde 4 farklı çeşit kan grubu bulunmaktadır.

C. Kan bağışında bulunmak kişilerin sağlığını bozar.

D. Kan alışverişinde Rh uyumluluğu önemlidir.

23. Küçük kan dolaşımında, kanın izlediği yol hangi seçenekte doğru verilmiştir?

Başlangıç ***Bitiş***

A. Sağ kulakçık → Akciğer atardamarı → Akciğer toplardamarı → Sol karıncık

B. Sağ karıncık → Akciğer toplardamarı → Akciğer atardamarı → Sol kulakçık

C. Sağ karıncık → Akciğer atardamarı → Akciğer toplardamarı → Sol kulakçık

D. Sol karıncık → Akciğer atardamarı → Akciğer Toplardamarı → Sağ kulakçık

24. Kan gruplarıyla ilgili aşağıdakilerden hangisi doğrudur?

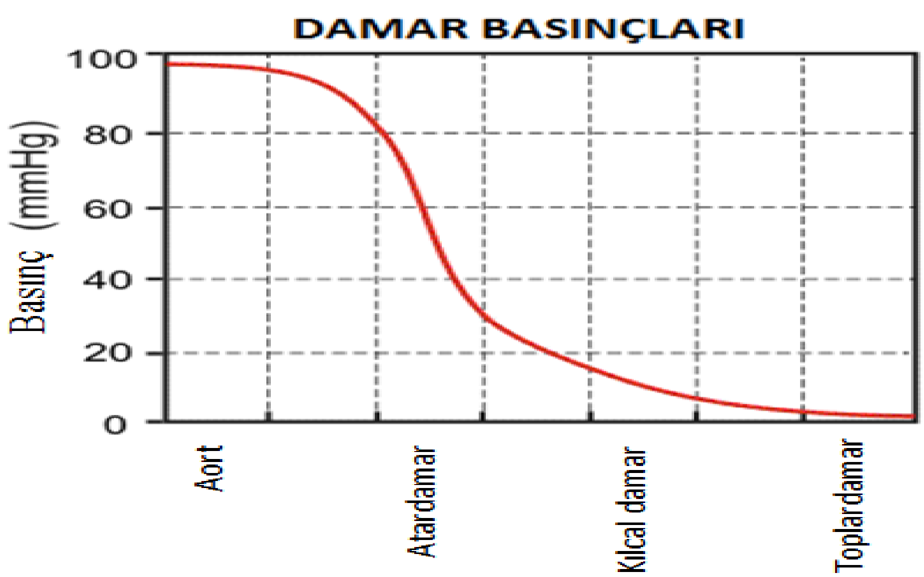
A. AB kan grubu genel vericidir.

B. 0 kan grubu genel alıcıdır.

C. En ideal kan alışverişi genel vericiden diğerlerinedir.

D. Kan gruplarında genel alıcı ve genel vericilik pratikte kullanılmaz.

25. Aşağıdaki grafikte dinlenme konumunda, insan kanının damarlara uyguladığı basınç gösterilmektedir.



Yukarıdaki grafiğe göre aşağıdakilerden hangisi doğrudur?

A. Toplardamarların basıncı kılcal damarlardan yüksektir.

B. Kan büyük dolaşım yaparken basıncı devamlı düşer.

C. Atardamarlarla toplardamarlar benzer basınçlara sahiptir.

D. En yüksek basınç kılcal damarlarda oluşur.

26. Aşağıda kan gruplarıyla ilgili verilen ifadeler için ne söylenebilir?

I- Alyuvarında Rh faktörü bulunan kan Rh(+) olarak adlandırılır.

II- Kan grupları alyuvarda bulunan antikor çeşidine göre belirlenir.

A. Her ikisi de doğrudur.

B. I doğru, II yanlıştır.

C. I yanlış, II doğrudur.

D. Her ikisi de yanlıştır.

27. Lenf dolaşımıyla ilgili aşağıdakilerden hangisi **yanlıştır**?

A. Kan dolaşımına yardımcı bir dolaşım sistemidir.

B. Kan damarları ve lenf damarlarından oluşur.

C. Lenf damarları içindeki akıcı maddeye lenf adı verilir.

D. Lenf damarları kandan hücreler arasına sızan maddeleri toplayarak yeniden kana kazandırır.

28. Lenf düğümleriyle ilgili aşağıda verilen ifadeler için ne söylenebilir?

I- Lenf düğümleri vücudu hastalıklara karşı korumakla görevlidir.

II- Bademciklerimiz birer lenf düğümüdür.

A. Her ikisi de doğrudur.

B. I doğru, II yanlıştır.

C. I yanlış, II doğrudur.

D. Her ikisi de yanlıştır.

29. Sağlık Bakanlığının araştırmaları sonucunda, Türkiye'de kalp ve damar hastalıklarına yakalananların sayısının gün geçtikçe arttığı gözlemlenmiştir. Bunun nedeni aşağıdakilerden hangisi ya da hangileri olabilir?

A. Tüketilen fastfood (ayaküstü tüketilen gıda) miktarının artması
B. Sigara kullananların sayısındaki artışlar
C. Egzersiz yapanların oranının düşüklüğü
D. Yukarıdakilerin hepsi

30. Aşağıdakilerden hangisi kan bağışının öneminden biri **değildir**?

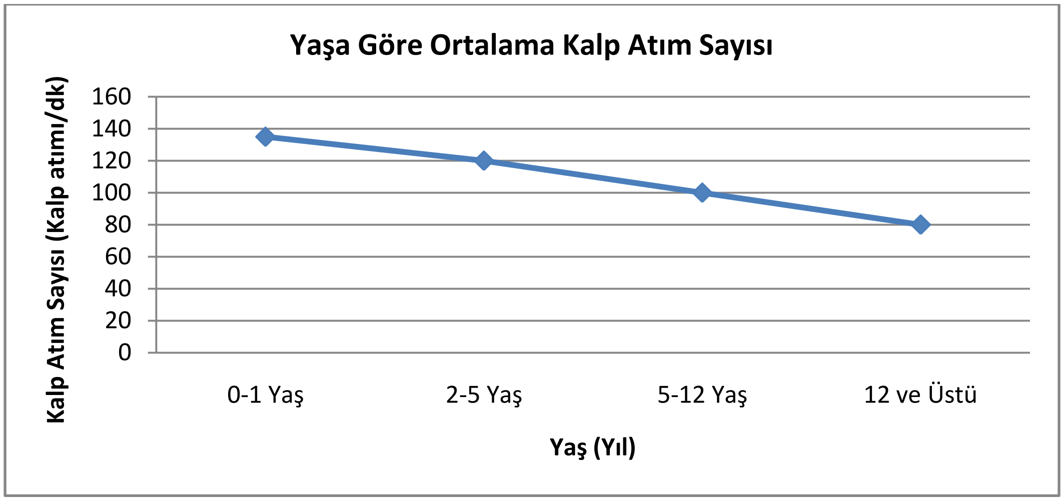
A. Sürdürülebilir kan stoku için önemlidir.
B. Kana ihtiyaç duyan kişilerin hayatını kurtarabilir.
C. Kilo vermeye yardımcı olur.
D. Kan bağışlarında yapılan tarama bazı hastalıkların erken teşhisini sağlar.

31. Büyük kan dolaşımında, kanın izlediği yol hangi seçenekte doğru verilmiştir

Başlangıç ***Bitiş***

A. Sol karıncık → Aort → Üst ana toplardamar → Sağ karıncık
B. Sağ karıncık → Aort → Üst ana toplardamar → Sol kulakçık
C. Sol kulakçık → Aort → Üst ana toplardamar → Sağ karıncık
D. Sol karıncık → Aort → Üst ana toplardamar → Sağ kulakçık

32. Aşağıdaki grafik, bir kişinin yaşına göre 1 dakikadaki ortalama kalp atım sayısını göstermektedir.



Bu grafiğe göre bu iki değişken (yaş ve kalp atım sayısı) arasında ilişki nasıldır?

A. Yaş arttıkça kalp atım sayısı artmaktadır.

B. Kalp atım sayısı ile yaş arasında herhangi bir ilişki yoktur.

C. Yaş arttıkça kalp atım sayısı azalmaktadır.

D. Yaş arttıkça kalp atım sayısı önce artmakta sonra azalmaktadır.

APPENDIX C

C. TEST OF SCIENCE RELATED ATTITUDES (TOSRA)

(FEN TUTUM TESTİ)

	Kesinlikle Katılmıyorum	Katılmıyorum	Kararsızım	Katılıyorum	Kesinlikle Katılıyorum
1. Önceki düşüncelerimle uyuşmayan konular hakkında okumaktan hoşlanırım.	❑	❑	❑	❑	❑
2. Fen dersleri eğlencelidir.	❑	❑	❑	❑	❑
3. Fen ile ilgili kulübe veya topluluğa katılmak isterim.	❑	❑	❑	❑	❑
4. Okulu bitirdikten sonra fen bilimleri alanında bilim insanı olarak çalışmak istemem.	❑	❑	❑	❑	❑
5. Her defasında aynı sonuçlara ulaşıp ulaşmadığımı kontrol etmek için yaptığım deneyleri tekrarlamaktan hoşlanmıyorum.	❑	❑	❑	❑	❑
6. Fen derslerinden hoşlanmıyorum.	❑	❑	❑	❑	❑
7. Evde televizyondaki fen ile ilgili programları izlerken sıkılıyorum.	❑	❑	❑	❑	❑
8. Okuldan mezun olduğumda fen alanında keşifler yapan insanlarla çalışmak isterim.	❑	❑	❑	❑	❑
9. Yaşadığımız dünya hakkında meraklıyım.	❑	❑	❑	❑	❑
10. Okulda haftalık ders programında daha fazla fen dersi olmalıdır.	❑	❑	❑	❑	❑
11. Fen ile ilgili bilimsel bir kitabın veya bir fen araç gerecinin hediye olarak bana verilmesinden hoşlanırım.	❑	❑	❑	❑	❑

12. Okuldan mezun olduktan sonra fen laboratuarlarında çalışmak istemem.	❑	❑	❑	❑	❑
13. Yeni şeyler keşfetmek önemsizdir.	❑	❑	❑	❑	❑
14. Fen dersleri beni sıkar.	❑	❑	❑	❑	❑
15. Tatil süresince fen ile ilgi kitaplar okumaktan hoşlanmam.	❑	❑	❑	❑	❑
16. Fen laboratuarında çalışmak geçim sağlamak için ilginç bir yol olabilir.	❑	❑	❑	❑	❑
17. Benden farklı görüşleri olan insanları dinlemeyi severim.	❑	❑	❑	❑	❑
18. Fen okuldaki en ilginç derslerden biridir.	❑	❑	❑	❑	❑
19. Evde fen ile ilgili deneyler yapmaktan hoşlanırım.	❑	❑	❑	❑	❑
20. Fen alanında kariyer sahibi olmak sıkıcı ve monotondur.	❑	❑	❑	❑	❑
21. Yeni fikirler hakkında bilgi edinmeyi sıkıcı bulurum.	❑	❑	❑	❑	❑
22. Fen dersleri zaman kaybıdır.	❑	❑	❑	❑	❑
23. Okuldan sonra arkadaşlarla fen dersi ile ilgili konular hakkında konuşmak sıkıcıdır.	❑	❑	❑	❑	❑
24. Mezun olduktan sonra fen ile ilgili konuları öğretmek isterim.	❑	❑	❑	❑	❑
25. Fen deneylerinde daha önce kullanmadığım yeni yöntemleri kullanmayı severim.	❑	❑	❑	❑	❑
26. Fen derslerinden çok hoşlanırım.	❑	❑	❑	❑	❑
27. Tatillerde fen laboratuarında bir iş imkânı bulmaktan hoşlanırım.	❑	❑	❑	❑	❑
28. Meslek olarak fen bilimleri alanında bilim insanı olmak sıkıcıdır.	❑	❑	❑	❑	❑
29. Eğer kanıtlar fikirlerimin yetersizliğini (zayıflığını) gösterirse fikrimi istemeyerek değiştiririm.	❑	❑	❑	❑	❑
30. Fen derslerinde işlenen konular ilginç değildir.	❑	❑	❑	❑	❑
31. Radyodan fen ile ilgili programları dinlemek sıkıcıdır.	❑	❑	❑	❑	❑
32. Fen alanında bilim insanı olmak bir iş olarak ilginç olabilir.	❑	❑	❑	❑	❑

33. Fen deneylerinde beklenen sonuçların yanında beklenmeyen sonuçları da raporuma yazarım.	❑	❑	❑	❑	❑
34. Fen derslerini sabırsızlıkla beklerim.	❑	❑	❑	❑	❑
35. Hafta sonları bilim müzesine gitmek bana zevk verir.	❑	❑	❑	❑	❑
36. Fen alanında bilim insanı olmak istemem çünkü uzun süreli eğitim gerektirir.	❑	❑	❑	❑	❑
37. Başkalarının fikirlerini dinlemekten hoşlanmam.	❑	❑	❑	❑	❑
38. Eğer fen dersleri olmasaydı, okul daha eğlenceli olurdu.	❑	❑	❑	❑	❑
39. Fen ile ilgili gazete makalesi okumaktan hoşlanmam.	❑	❑	❑	❑	❑
40. Okuldan mezun olduğumda fen alanında bilim insanı olmak isterim.	❑	❑	❑	❑	❑

APPENDIX D

D. VIEWS OF NATURE OF SCIENCE ELEMENTARY SCHOOL VERSION (VNOS-E)

(BİLİMİN DOĞASI ÖLÇEĞİ: FORM-E)

1. Sizce "bilim" nedir?

2. a) Sizce bilimi diğer konulardan (resim, müzik, Türkçe gibi) ayıran özellikler nedir? Örnek vererek açıklayınız.

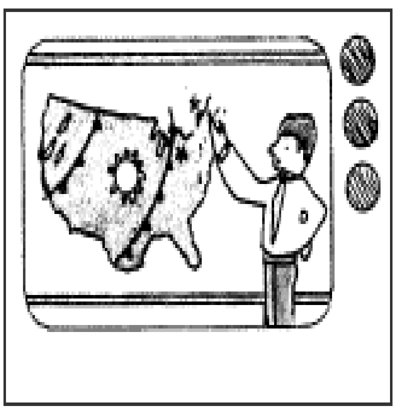
   b) Bilim sizce bu konulardan (resim, müzik, Türkçe gibi) hangi açılardan farklıdır? Açıklayınız.

3. Bilim insanları daima dünyamız hakkında daha çok bilgi sahibi olmaya çalışırlar. Bilim insanlarının bugün sahip oldukları bilgilerinin gelecekte değişeceğini düşünür müsünüz? Lütfen örnekler yardımıyla açıklayınız.

4. a) Bilim insanları bir zamanlar dinozorların dünyada yaşadıkları hakkında nasıl bilgi sahibi olmuşlardır?

   b) Bilim insanları dinozorların görünüşleri hakkında nasıl bilgi sahibi olmuşlardır? Sizce bu konuda kesin bilgilere sahip midirler? Nedenleriyle açıklayınız.

5. Bilim insanları; dinozorların uzun bir zaman önce, neden ve nasıl yok olduğu konusunda farklı görüşlere sahiptirler. Bilim insanları aynı veri ve kanıtlara sahip olmalarına rağmen dinozorların yok oluşlarıyla ilgili olarak neden farklı görüşlere sahiplerdir?

6. 

Her gün televizyonda hava durumu spikeri yarın havanın nasıl olacağına dair bilgileri resimlerle bize aktarmaktadır. Bu resimlerin hazırlanmasında birçok bilimsel veriler ve kanıtlar kullanılır. Hava durumu spikeri bu resimlerin verdiği bilgiler hakkında nasıl emin olabilmektedir? Nedenleriyle birlikte açıklayınız.

7. Bilim insanlarının çalışmalarında hayal gücü ve yaratıcılıklarını kullandıklarını düşünür müsünüz?

- ☐ Evet
- ☐ Hayır

a) Eğer cevabınız “hayır” ise neden böyle düşündüğünüzü örneklerle açıklayınız.

b) Eğer cevabınız “evet” ise sizce bilim insanları hayal gücü ve yaratıcılıklarını araştırmalarının; planlama, deney yapma, gözlem yapma, verileri analiz etme, sonuçları açıklama ve yorumlama gibi aşamaların hangisinde kullanırlar? Lütfen bilim insanlarının neden hayal gücü ve yaratıcılıklarını kullandığını örneklerle açıklayınız.

APPENDIX E

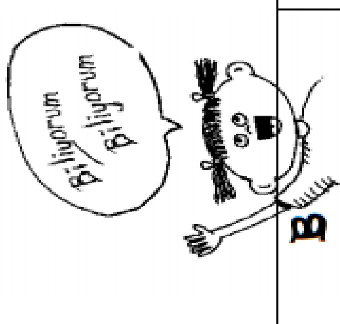
E. KWL CHART

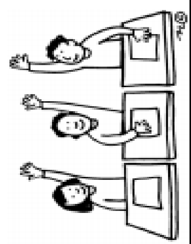
Konu: DOLAŞIM SİSTEMİ

İsim:__________ Tarih:__________

Aşağıdaki grafik düzenleyiciye bilgilerini organize etmek için kullanınız.

BİÖ





B Ne Biliyorum?	İ Ne Öğrenmek İstiyorum	Ö Ne Öğrendim?

APPENDIX F

F. DRAW A SCIENTISTS ACTIVITY SHEET

(BİLİM İNSANI ÇİZELİM ETKİNLİK FORMU)

ETKİNLİK 1

---Bilim İnsanı Çizelim---

İsim: ______________________________ Sınıf: _____________

Aşağıdaki kutucuğa bir bilim insanı çizin, çiziminizi yaparken yaptığı işi de çizmeyi unutmayın!

Çizdiğiniz Bilim İnsanının Adını Yazınız:

ÇİZDİĞİMİZ BİLİM İNSANINI TANIMLAYALIM.

Kişisel Özelliklerini Yazınız:

Çalışma Ortamını Tarif Ediniz:

Yaptığı İşi Tarif Ediniz:

Çizdiğiniz Bilim İnsanı Resimde Ne Yapıyor:

____

Adapted from: Fralick, B., Kearn, J., Thompson, S., & Lyons, J. (2009). How Middle Schoolers Draw Engineers and Scientists. *Journal Of Science Education & Technology*, *18*(1), 60-73. doi:10.1007/s10956-008-9133-3

APPENDIX G

G. HISTORICAL SHORT STORY 1

(KALP HAKKINDA NE BİLİYORDUK)

ETKİNLİK 2

---Kalp Hakkında Ne Biliyorduk---

Grup Adı_________________________ Sınıf:______________

Gruptaki Kişiler:____

Tarihsel Süreçte Kalp

Tarih boyunca kalp, hem görevi açısından, hem de sembolik olarak önemli bir organ olarak görülmüştür. Kalbin nasıl çalıştığı ve ne işe yaradığı değişik toplumlardaki bilim insanlarının zihnini meşgul eden bir konu olmuştur.

Eski Hint toplumları kalbi, sinir sistemini oluşturan yapıların vücudun kısımlarına ulaşmak için çıktığı merkez olarak düşünüyorlardı. Bilim tarihinde, ilk diseksiyon yöntemini kullanan anatomistlerden biri olarak bilinen Empedokles'e göre kalp, vücudun yaşamsal ısı kaynağının dağıtım merkeziydi. Ünlü yunan hekim Hipokrat, karaciğer ve dalağın kan üreten merkez organlar olduğuna ve bu kanın soğutulmak ya da ısıtılmak amacıyla kalbe geldiğine inanıyordu. Aristoteles'e (filozof ve biyolog) göre kalp; bilinç, zekâ ve beş duyumuzun kontrol edildiği merkezdi. Herofilüs (Yunan Hekim) bu fonksiyonları kalp değil de beynin gerçekleştirdiğini kanıtlamıştır. Erasistratus ortaya attığı yeni bir teoriyle kalbin pompa görevinin olduğunu ileri sürdü. Teorisinde kalbin kulakçıklarını ve kan damarlarını (aort, akciğer atar ve toplardamarları, üst ve alt ana toplardamar) tanımladı. Eski anatomistlerin fikirleri çoğunlukla eksik olmasına rağmen daha sonra yapılan bilimsel gelişmeler için temel oluşturmuştur

Galen (131-192) şu anda İzmir'in bir ilçesi olan Bergama'da doğmuştur. İyi bir hekim olan Galen'in yazıları anatomiden (vücut yapısı) tedavi yöntemlerine kadar tıbbi bilginin bütün yönlerini oluşturuyordu. Yüzyıllar boyunca Galen öyle itibar kazandı ki hiç kimse bulgularının ve fikirlerinin doğruluğunu sorgulamaya cesaret edemedi.
Galen'e göre kalp; akciğerleri beslemek üzere sahip olduğu kanın bir kısmını sağ karıncığından akciğerlere pompalıyordu. Kalan kısım karıncık duvarlarındaki gözeneklerden sol karıncığa geçiyordu. Burada akciğerden gelen hava ile birleşiyordu. Galen, bu solunan havanın yaşamın temel prensiplerini içerdiğine inanıyordu.
William Harvey (İngiliz Hekim) kalbin vücuda kan pompaladığını kanıtladı. Kalbin kaslı bir yapıya sahip olduğunu; karıncık duvarlarında gözenekler olmadığını, dolaşım sisteminin merkez organının kalp olduğunu ispatlamıştır. Küçük düzenlemeler yapılmış olmasına rağmen, modern fizyolojide kalbin yapısı ve görevleriyle ilgili halen kabul gören görüş Harvey'e aittir.

SORULAR

Yukarıda tarihsel süreçte bilim insanlarının ve toplumların kalp, kalbin yapısı ve görevleri ile ilgili bilimsel makalelerde yayınlanan özet bilgiler okudunuz. Bu bilgilere göre aşağıdaki sorulara cevap veriniz.

1. Aşağıdaki tabloyu okuduğunuz bilgilere göre doldurunuz.

Bilim İnsanı	Mesleği/Uzmanlık Alanı	Kalp ile İlgili Görüşü

2. Yukarıdaki özet bilgiyi okuduktan sonra bilim insanlarının kalbin yapısı ile ilgili bilgilerinden ne kadar emin olduklarını düşünüyorsunuz? Açıklayınız.

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3. Sizce bilim insanlarının kalp ile ilgili bilgileri değişmez midir? Açıklayınız.

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4. Yukarıdaki özet bilgiyi göz önünde bulundurunca sizce bilimsel bilgi bir kesinliğe ya da değişmezlik özelliğine sahip midir? Cevabınızı açıklayınız.

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Azizi, M. H., Nayernouri, T., & Azizi, F.(2008). A brief history of the discovery of the circulation of blood in the human body. *Archives of Iranian Medicine, 11*(3), 345-350.

Gross, C. G. (1995). Aristotle on the brain. *The Neuroscientist, 1*(4), 245-250.

A history of the heart. (n.d.) Retrieved December 24, 2011, from http://www.stanford.edu/class/history13/earlysciencelab/body/heartpages/heart.html

Malomo, A. O., Idowu, O. E., & Osuagwu, F. C. (2006). Lessons from history: Human anatomy, from the origin to the renaissance. *International Journal of Morphology, 24*(1), 99-104.

APPENDIX H

H. STRUCTURE AND THE FUNCTION OF THE HEART

(KALBİN İÇİNE BAKALIM)

ETKİNLİK 3

---Kalbin İçine Bakalım---

İsim: ______________________ Sınıf: ______________

1. **Kalbin dış kısmıyla ilgili gözlemler yaptınız. Gözlemlerinizde edindiğiniz bilgilere göre aşağıdaki soruları cevap veriniz.**

Şekli nasıl?

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Yapıları hangi renk?

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Hangi kısmı daha kaslı, hangi kısım daha az kaslı?

Büyüklüğü ne kadar?

Yapısında damar var mı?

Diğer gözlemlerim?

2. **Kalbin dış yapısıyla ilgili gözlemlerinizi aşağıdaki kutucuğa çiziniz.**

3. **Kalbin iç kısmıyla ilgili gözlemler yaptınız. Gözlemlerinizde edindiğiniz bilgilere göre aşağıdaki sorulara cevap veriniz.**

Kaç bölümden oluşuyor?

Damarlar çıktığı bölgeler neresi?

Damarların büyüklükleri nasıl?

Diğer gözlemlerim?

4. Kalbin içyapısıyla ilgili gözlemlerinizi aşağıdaki kutucuğa çiziniz

5. Kalbin dış yapısında damarlar olduğunu gözlemledik. Sizce bu damarların görevleri ne olabilir?

6. Kalbin karıncık kısmının kulakçık kısmına göre daha kaslı bir yapıya sahip olduğunu gözlemledik. Sizce bunun sebebi ne olabilir?

7. Bu gözlemlerinize göre kanı vücuda pompalayan kısım hangisidir?

APPENDIX I

I. HISTORICAL SHORT STORY 2

(KANIN YAPILARI)

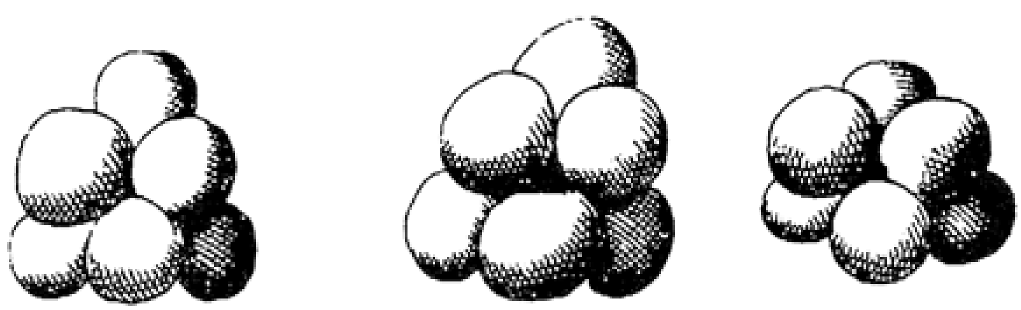
ETKİNLİK 4

---Kanın Yapısı---

İsim: ______________________ Sınıf: _____________

KANIN YAPILARI

Kanın çıplak gözle incelenmesi çok eski zamanlara dayanmaktadır. Bu zamanlarda kanın, renginden dolayı, yalnızca kırmızı taneciklerden oluştuğu düşünülmekteydi. Mikroskobun icadı kanın yapısı ile ilgili ilk bilimsel çalışmaların yapılmasına olanak sağlamıştır. 1658 yılında ilk defa Alman doğa bilimci, Jan Swammerdam, mikroskop altında kırmızı kan hücrelerini gözlemlemiştir. Alman mikroskop uzmanı, Antoni van Leeu-wenhoek, ise 1695 yılında kırmızı kan hücrelerinin büyüklük ve şeklini tanımlayıp resmetti. Resim 1'de Leeu-wenhoek tarafından resmedilen kırmızı kan hücreleri görülmektedir.



Resim 1. Leeu-wenhoek tarafından çizilen kırmızı kan hücreleri

Sonraki 150 yıl içinde, mikroskop altında kana bakanlar kırmızı kan hücresinden başka bir şey göremediler. Ta ki 1843 yılında Fransız tıp profesörü Gabriel Andral ve İngiliz pratisyen hekim William Addison aynı zamanda birbirinden bağımsız olarak beyaz kan hücrelerini tasvir etti. 1842 yılında Fransız halk sağlığı uzmanı Alfred Donne kanın üçüncü bir yapıtaşı olan kan pulcuklarını keşfetti. Donne meslektaşları tarafından çok fazla umursanmamasına ve hatta meslektaşlarının ona düşmanca tavırlar sergilemesine rağmen, mikroskobun tıpta kullanılması ile ilgili çalıştaylar düzenlemiş; bu çalıştaylar Fransız öğrencilerinin yanı sıra diğer yabancı öğrencilerin de ilgisini çekmiştir.

Hajdu, S. I. (2003). A note from history: The discovery of blood cells. *Annals of Clinical & Laboratory Science, 33* (2), 237-238.

-----------SORULAR----------

1. **Okuduğunuz parçada, kanın yapısında neler olduğunun keşfedilmesi sürecinde tarih boyunca nasıl gelişmeler olduğu ve hangi süreçlerden geçtiği kısaca anlatılmıştır? Bu bilgilere göre aşağıdaki tabloyu doldurunuz.**

Bilim İnsanı /Devir	Kan ile ilgili keşif / fikir
İlk zamanlar	
Jan Swammerdam	
Antoni van Leeu-wenhoek	
Gabriel Andral	

William Addison	
Alfred Donne	

2. Sizce kanın yapısıyla ilgili daha gerçekçi bilgiler mikroskobun keşfinden önce mi yoksa sonra mı ortaya çıkmıştır? Neden?

3. Okuduğunuz parçaya göre bilimsel bilgiyi diğer bilgilerden ayıran özellikler nelerdir?

APPENDIX J

J. CONSTITUENTS OF BLOOD

(KANIN YAPISI VE GÖREVLERİ)

ETKİNLİK 5

---Kanın Yapısı Ve Görevleri---

İsim: ______________________ Sınıf:______________

1. Mikroskopta daimi kan preparatlarını gözlemleyiniz. Gözlemlerinizi aşağıdaki boşluğa çiziniz.

2. Mikroskopta incelediğiniz örnekte kaç çeşit hücre gördünüz? Açıklayınız.

3. Gördüğünüz hücrelerin şekilleri nasıldı? Açıklayınız.

4. Sizce kanın yapısında gözlemlediklerinizden başka hücreler olabilir mi? Açıklayınız.

5. Sizce bu gözlemlediğiniz hücrelerin görevleri aynı mıdır? Neden?

6. “Kalbin İçine Bakalım” etkinliğinde gözlem ile çıkarım arasındaki farkı öğrendiniz. Kanın akıcı olduğunu göz önünde bulundurarak sizce kanın akıcı olmasını sağlayan nedir? Çıkarımınızı aşağıya yazınız.

APPENDIX K

K. HISTORICAL SHORT STORY 3

(DOLAŞIM SİSTEMİ HAKKINDA)

ETKİNLİK 6

---Dolaşım Sistemi Hakkında---

İsim: ______________________ Sınıf: ____________

Harvey'in dolaşım sistemindeki buluşlarını tümüyle takdir etmek için Yunanistan'ın altın çağı olan M.Ö. 400'lü yıllara dönmek gerekir. O yıllarda Helenist (Yunan) medeniyeti yağmur yağması ya da hastalık gibi gündelik olayların çeşitli ruhların elinde olduğunu görüşünü reddediyordu. Bu olayları doğaüstü değil doğal olaylar olduğuna vurgu yaparak bu olayların sebeplerini eleştirel ve akılcı bir analize bağlanması gerektiğini düşünüyordu. Bu yönüyle efsaneden mantığa ya da sebep aramaya geçiş yaptılar.

Tıp alanında William Harvey'den önce Galen'in kalp ve dolaşımla ilgili görüşleri1600 yıl boyunca etkili olmuştur. Galen'in tıbba en önemli katkılarından birisi "Kan Dağılım Teorisi"dir. Galen'in teorisine göre kan karaciğerde, mide ve bağırsaklardan gelen besinlerden, üretiliyordu. Üretilen bu kan besin maddesi olarak ya da et gibi yumuşak dokulara dönüşmek üzere damarlar yoluyla vücuda dağıtılıyordu. Geri kalan kan kalbin sağ karıncığına geliyordu. Bu kanın bir kısmı akciğeri beslemek üzere akciğere gönderiliyor kalanı karıncık duvarındaki gözeneklerden sol karıncığa boşalıyordu. Burada bu kan akciğerden gelen hava ile birleşiyor, böylece yaşamın temel prensiplerini içerdiğine inanılıyordu. Kalp genişlemesi sırasında kanı sağ karıncığa, havayı sol karıncığa emdiği düşünülüyordu. Kalp kasıldığı zaman sağ karıncıktaki kanı akciğere, sol karıncıktakini vücuda gönderiyordu. Kalp genişlediği ve kanla dolduğunda (diyastolde) aktif olarak iş yapmakta olduğu ve kalp atışının bu sırada oluştuğu görüşü hâkimdi. Mevcut kan vücutta devamlı olarak tüketiliyordu. Eksilen kan sindirilen besinlerden yeniden üretiliyordu.

William Harvey 1578 yılında Folkstone'da doğdu. İlk tıp eğitimini ünlü tıp okullarından Padua'da aldı. Kazandığı başarılar, 1615 yılında Kraliyet Tıp Okulu'nun anatomi ve cerrahi kürsüsüne öğretim üyesi olarak atanmasını sağladı.

Harvey, 1616 yılında kraliyet tıp okulunda hocayken yaptığı deneylere ve hayvanlar üzerindeki gözlemlere dayanarak kan dolaşımını tarif etmeye başladı. Öncelikle viviseksiyon (tıbbi amaçlı canlı hayvan üzerinde inceleme ve araştırma yapma) yöntemini kullandı. Canlı bir hayvanın kalbini vücudundan ayırınca kalbin bir müddet daha atmaya devam ettiğini gözlemledi. Böylece Galen'in düşündüğünün tersine, kalbin genişleyince kanı emen bir organ olmadığını, aksine kalbin bir pompa gibi çalıştığını kanıtladı. Aynı şekilde canlı bir hayvanın kalbi durmaya başladığında kalbin hareketini daha iyi gözlemleyip Galen'in söylediğinin tam aksine; kalbin küçükken, sert ve kasılmış halde (sistolde) kanı pompalayarak aktif olarak iş yaptığını; genişlediği ve kanla dolduğunda (diyastolde) dinlenme haline geçtiğini ispatladı. Harvey'in viviseksiyon yöntemiyle ispatladığı diğer bir bulgu ise kulakçıkların kasılmasıyla kanın karıncıklara geçtiğidir. Harvey canlı bir hayvanın kalbinin karıncığını makas yardımıyla kestiğinde kulakçıkların her kasıldığında kanın karıncıklardan fışkırdığını gözlemledi. Böylece karıncıklara kanın nasıl geldiğini doğru bir şekilde ispatlamış oldu. Harvey'in dolaşım sistemi ile ilgili sonuçlara ulaşmak için kullandığı diğer viviseksiyon yöntemleri şöyle özetlenebilir:

- Balıklarda kalpten çıkan atardamarı kesince her kalp atımında kanın kesilen yerden fışkırdığını gözlemleyip atardamarların genişlemesinin kalbin kasılmasını takip ettiğini buldu.

- Koyunlarda toplardamarı kestiğinde toplardamarın kalbe giden yönünde daimi kan akışı olduğu diğer tarafında ise kan akışının olmadığını gözlemleyerek toplardamarda kanın yönünün vücuttan kalbe doğru olduğu; aynı işlemi atardamara yaptığında tam tersi bir sonuç gözlemleyip atardamarlarda kanın yönünün kalpten vücuda doğru olduğunu ispatlamıştır.

Harvey'in dolaşım sistemini tarif ederken kullandığı ikinci bir yöntem diseksiyondur (ölü insan ve hayvan vücudunun kısımlarını deney amaçlı inceleme). Diseksiyon yolu ile bulduğu sonuçlar özetle şöyledir:

- Kalbi keserek karıncık duvarlarının kalın, sert, yoğun olduğunu, bu duvarlarda gözenekler olmadığını vurguladı.
- Toplardamarlarda kapakçıklar olduğunu bu kapakçıkların kanın geriye gidişini engellediği bu sayede Galen'in düşündüğü gibi toplardamarlarda kanın gel git yapamayacağını, toplardamarlarda kanın tek yönde hareket ettiği çıkarımını yapmıştır.

Harvey'in dolaşım sisteminde kullandığı diğer bir yöntem nicel, matematiksel yöntemdir. Bu yöntemi kullanırken aynı anda viviseksiyon ve diseksiyon yöntemlerinden yararlanmıştır. Bu yöntemle kanın tüketilip yediğimiz yiyeceklerden tekrar üretilemeyecek kadar çok olduğunu; kanın mutlaka vücutta dolaşması gerektiğini öne sürmüştür. Bu yöntemin özü şuna dayanır:

- Harvey diseksiyon yoluyla elde ettiği kalbin sol karıncığının hacmini ölçer ve yarım saat içinde insanın kalbinden geçecek olan kan miktarını hesaplar. Hesaplarına göre bu miktar vücuttaki toplam kandan fazladır. Bu da kanın vücutta dolaştığının ispatıdır.

Harvey dolaşım sistemi ile ilgili çalışmalarında perfüzyon (Bir sıvıyı bir organa ya da dokuya damar yoluyla verme işlemi) yöntemini de kullanmıştır. Bu yöntemle Harvey:

- Kalbe giren ve çıkan bütün damarları bağlayıp ve alt ana toplardamardan kalbe su verince sağ karıncığın şiştiğini gözlemlemiştir. Sol karıncığı kesmesine rağmen buradan su çıkışı olmamıştır. Eğer karıncıklar arasında gözenekler olsaydı sol karıncıktan su çıkışı gözlemlenecekti.

Daha sonra bu bulgularını bir araya toplayıp dolaşımla ilgili bugün hala neredeyse değişmeden kabul edilen teorisini ortaya koymuştur.

SORULAR

1. Okuduğunuz parçaya göre sizce Harvey ve Galen dolaşım sistemi hakkında neden farklı düşünüyorlardı?

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2. Galen'in ortaya attığı teorinin 1600 yıl değişmeden kalmasının sebebi ne olabilir?

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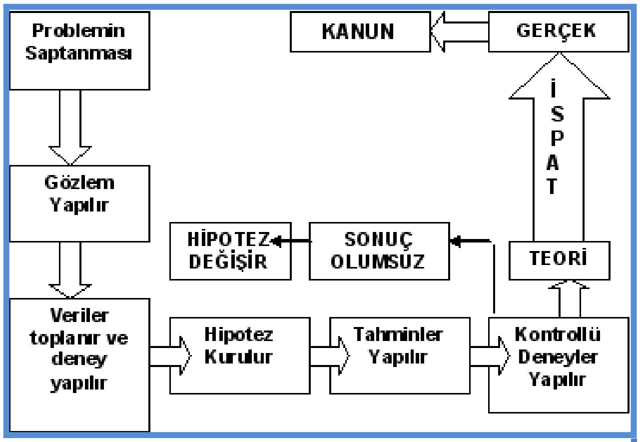
3. Harvey dolaşım sistemi ile ilgili teorisini geliştirirken hangi yöntemlerden faydalanmıştır?

4. Bilim çevresinde, Harvey'in dolaşım sistemiyle ilgili geliştirdiği teorinin Galen'in teorisinin yerine kabul görmesinin nedenleri ne olabilir?

5. Okuduğunuz parçaya göre bilim insanları bir problemi çözmeye çalışırken aynı yöntemleri mi kullanırlar? Neden?

6. Yanda şekilde kitaplarda gösterilen "genel geçer" bilimsel yöntem basamakları verilmiştir. Bu parçayı okuduktan sonra bu basamakların doğruluğu ile ilgili ne düşünüyorsunuz?



7. Birçok insan bilim insanlarını laboratuarda çalışıyor olarak hayal eder. Yukarıda okuduklarınıza göre Harvey'in bu bilim insanlarından farkı nedir?

Özkaynak, B. (2006). *Atan kalpte koroner revaskülarizasyon cerrahisinin postoperatif uzun dönem sonuçlarının değerlendirilmesi.* Uzmanlık Tezi, İstanbul, Türkiye

Prof. Dr. Ayten Altıntaş. Tıp Tarihi Ders Notları

Ribatti, D. (2009). William Harvey and the discovery of the circulation of the blood. *Journal of Angiogenesis Research, 1*(3), 1-2.

Schultz, S. G. (2002). William Harvey and the circulation of the blood: The birth of a scientific revolution and modern physiology. *News in Physiological Science, 17*, 175-180.

Shank, M. H. (1985). From Galen's ureters to Harvey's veins. *Journal of the History of Biology, 18*(3), 331-355.

Westfall, R. S. (1977). *The Construction of Modern Science.* Modern Bilimin Oluşumu Çeviri: İsmail Hakkı Duru

APPENDIX L

L. PULMONARY CIRCULATION AND SYSTEMIC CIRCULATION

(KÜÇÜK VE BÜYÜK KAN DOLAŞIM MODELİ)

Etkinlik 7

---Küçük Ve Büyük Kan Dolaşım Modeli---

Grup Adı____________________ Sınıf:______________

Gruptaki Kişiler:____

Önbilgi

- Kalbin sağ kısmında her zaman kirli; sol kısmında her zaman temiz kan bulunur!
- Vücuda kan her zaman karıncıktan pompalanır, vücuttan gelen kan her zaman kalbin kulakçığına gelir!
- Atardamar her zaman kalpten kanı vücuda taşır!
- Toplardamar her zaman kanı vücuttan kalbe getirir!

1. Yukarıdaki bilgilere dayanarak ve size verilen materyalleri kullanarak küçük kan dolaşımıyla ilgili bir model oluşturunuz ve bu modeli aşağıdaki kutucuğa çiziniz.

2. Yukarıdaki bilgilere dayanarak ve size verilen materyalleri kullanarak büyük kan dolaşımıyla ilgili bir model oluşturunuz ve bu modeli aşağıdaki kutucuğa çiziniz.

3. Büyük ve küçük kan dolaşımın modelini tek model üzerinde birleştirin ve birleştirdiğiniz modeli aşağıdaki boşluğa çiziniz

4. Sizin yaptığınız modelle diğer grupların modelleri arasındaki benzer ve farklı yönler nelerdir? Açıklayınız.

Benzerlikler:____

____

____

____

Farklılıklar:____

____

____

____

____

____

5. Sizce bu benzerlik ve farklılıkların nedeni ne olabilir? Açıklayınız.

6. Sizce bilim insanları da bilimsel olayları açıklarken model kullanırlar mı? Açıklayınız.

7. Sizce farklı bilim insanları aynı olayı açıklarken farklı modeller oluştururlar mı? Açıklayınız.

8. Bilim insanları elde ettikleri verilerden modeller oluştururken yaratıcılık ve hayal gücünü kullanırlar mı?

APPENDIX M

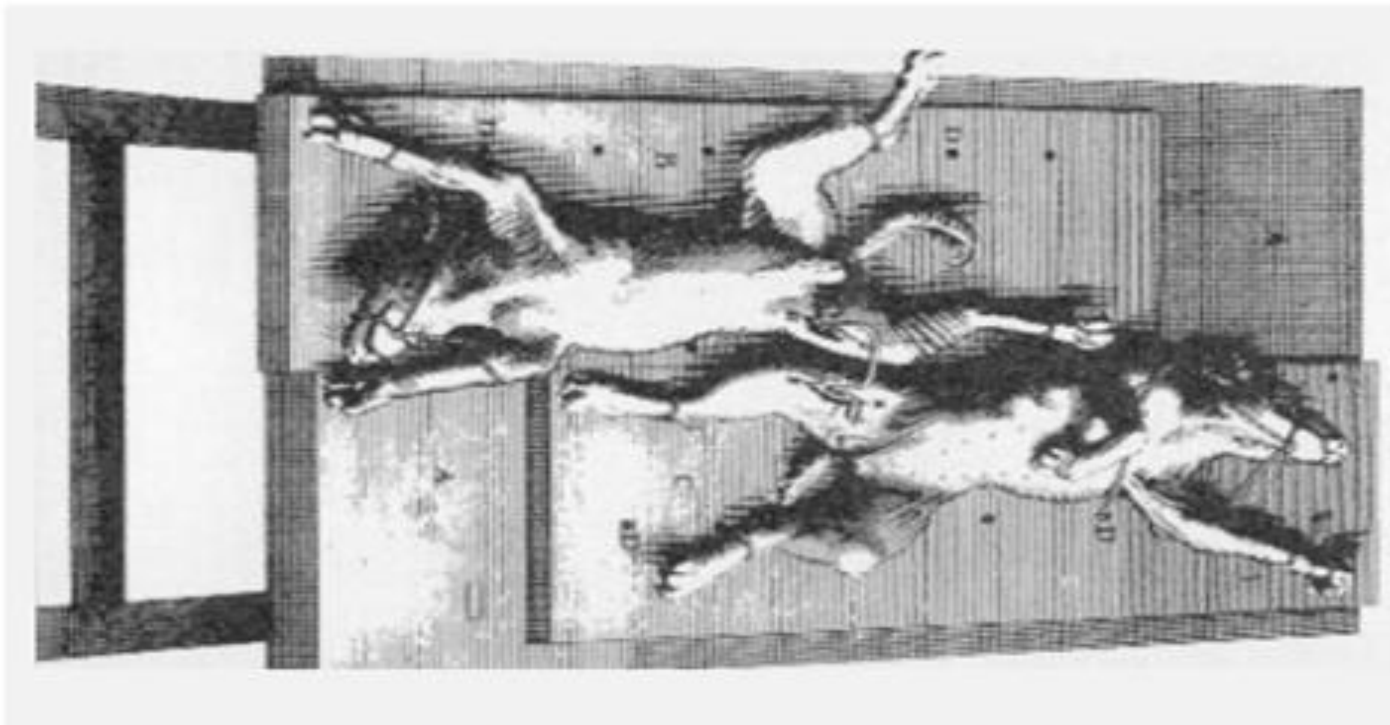
M. BLOOD TRANSFUSION TIMELINE

(KAN NAKİL ZAMAN ÇİZELGESİ)

Yıl: 1492

XV ve XVI. yüzyılda genç insanların kanının yaşlılara nakledilmesiyle yaşlılığın önlenebileceği düşünülüyordu. Bu düşünceyle Papa'ya on yaşındaki üç çocuktan kan nakledilmişti. Sonuç maalesef beklendiği gibi olmadığı gibi, hem Papa hem de üç çocuk bu olayın ardından hayatlarını kaybetmişlerdir.

Yıl: 1665



Tarihi kayıtlara göre ilk başarılı kan nakli İngiltere'de yapılır: Doktor Richard Lower diğer köpeklerden aldığı kan ile yaralı bir köpeği hayatta tutmayı başarır.

Yıl: 1667

Fransa'dan Jean-BaptisteeDenis ve İngiltere'den Richard Lower ve Edmund King birbirlerinden bağımsız olarak bir insana ilk defa başarılı bir kan nakli gerçekleştirmişlerdir. Bu olayda ilginç olan nokta ise insana nakledilen kanın bir koyundan alınmış olmasıdır.

Yıl: 1678

Hayvanlardan insanlara kan nakli çok farklı şekillerde denenmiş ve birçok ölümle sonuçlanan vakalar gözlemlenmiştir. Bu yüzden hayvanlardan insanlara kan nakli Paris Hekimler Derneği'nce yasadışı ilan edilmiştir.

Yıl: 1818

İngiliz kadın doğum uzmanı James Blundell, bir insandan diğerine kan nakli yapan ilk bilim insanı olarak tarihe geçmiştir. Bu nakil, doğum sonrası kanaması olan bir kadına, kocasından alınan kan nakledilerek gerçekleştirilmiştir.

Yıl: 1873-1880

Bu tarihler arasında Amerikalı araştırmacılar, insanlara kan yerine inek ve keçi sütü nakletmişlerdir.

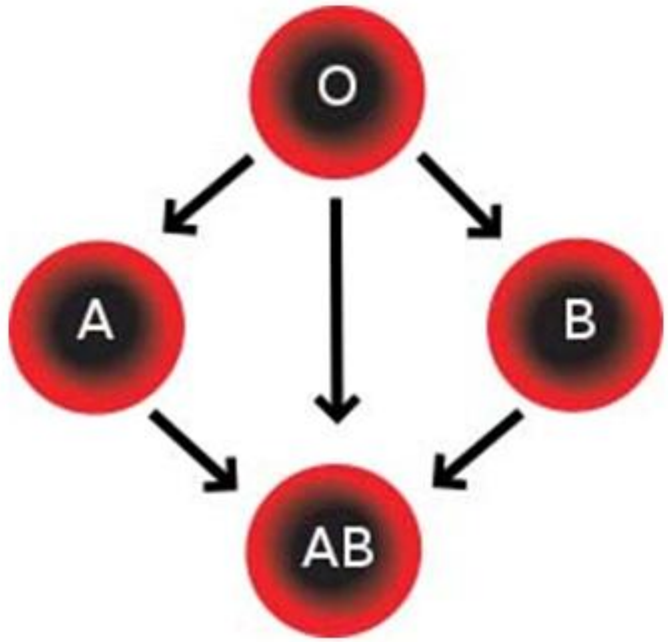
Yıl: 1884

Süte bağlı yan etkilerin çok sık görülmesi üzerine kan ihtiyacını karşılamak için süt yerine tuzlu su insanlara nakledilmeye başlandı.

Yıl: 1901

Karl Landsteiner ilk defa 3 kan grubunu keşfederek bunlara A, B ve C grupları adını verdi. Landsteiner'in bu çalışması önceleri kimsenin dikkatini çekmemiştir; fakat buluşundan tam 29 yıl sonra bu çalışmasıyla Nobel Tıp Ödülünü almaya layık görülmüştür.

Yıl: 1902



Kan grupların dördüncüsü olan AB grubu, Karl Landsteiner’in öğrencileri Decastrello ve Sturli tarafından keşfedilmiştir.

Yıl: 1928

Rus felsefeci ve bilim insanı olan Alexander Bogdanov kan değişimi sayesinde yaşlanmayı engelleyebileceğini düşünüyordu. Bu amaçla kendi üzerinde uyguladığı bir deney sırasında, öğrencisinden kaptığı sıtma ve tüberküloz bakterileri nedeniyle hayatını kaybetmiştir.

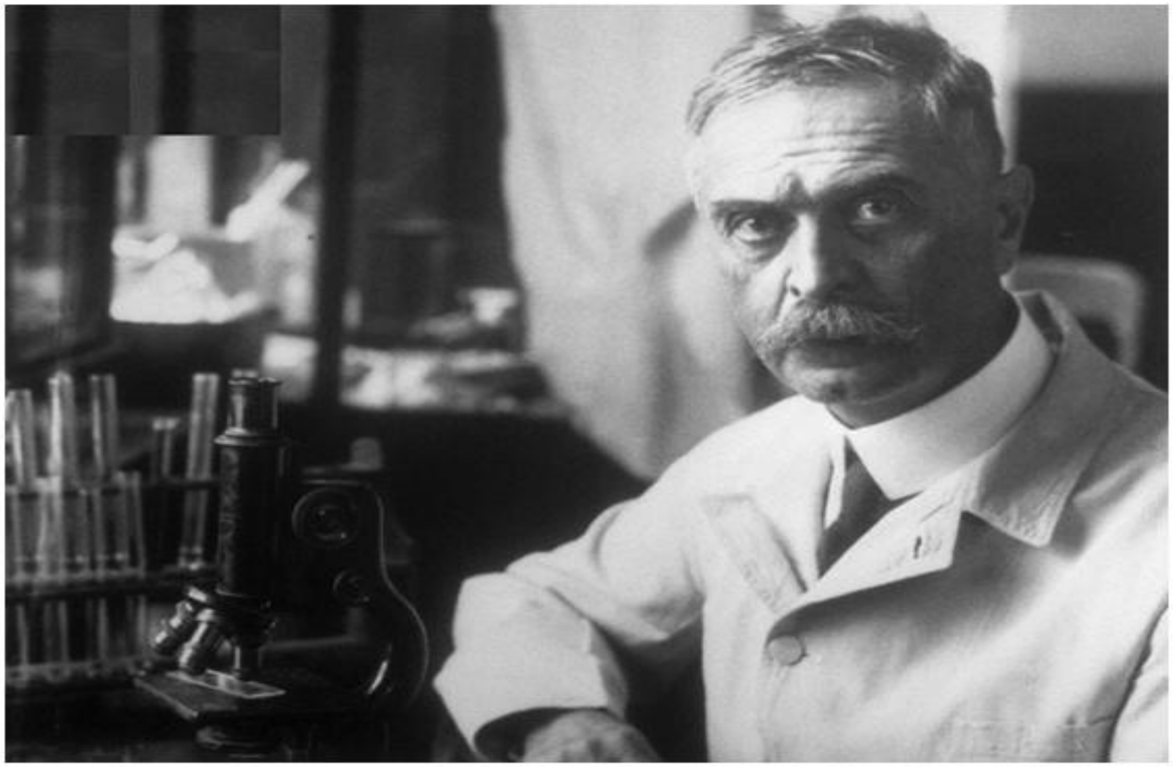
Yıl: 1930

Rus profesör Viladimir Shamov ilk kez bir kadavradan (ölü insan vücudu) canlıya kan nakli gerçekleştirmiştir. Shamov bu yıllarda toplamda 2500 kişiye kadavradan nakil yaptığını rapor etmiştir.

Yıl: 1938

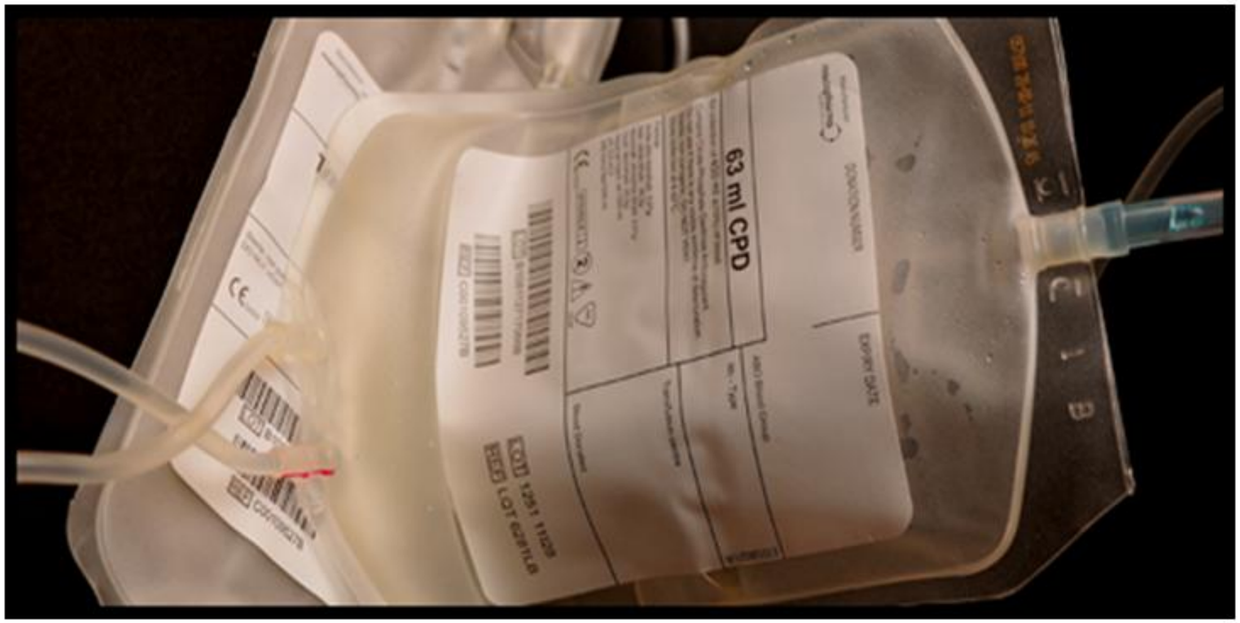
İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi'nde ilk kan nakli gerçekleşmiştir.

Yıl: 1940



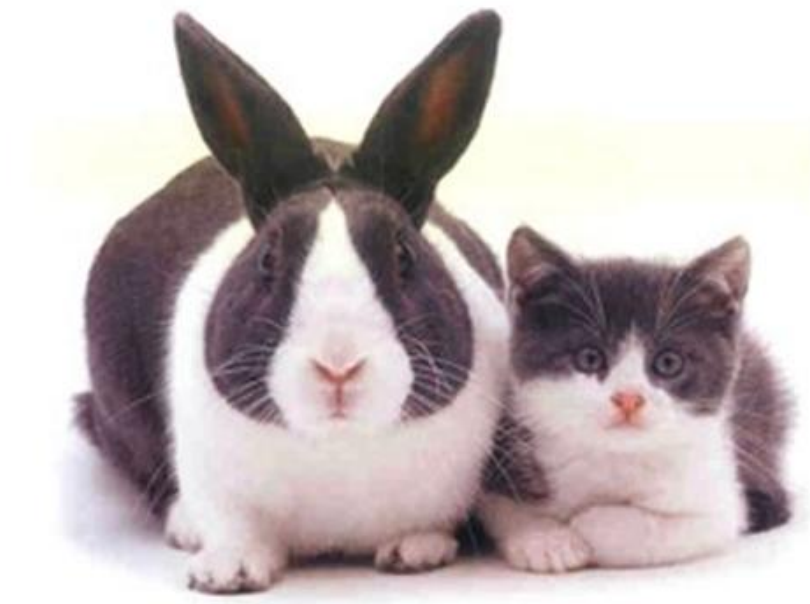
Karl Landsteiner ve ekibi yine iş başındadır ve bu kez kandaki Rh faktörünü keşfederler.

Yıl: 1950



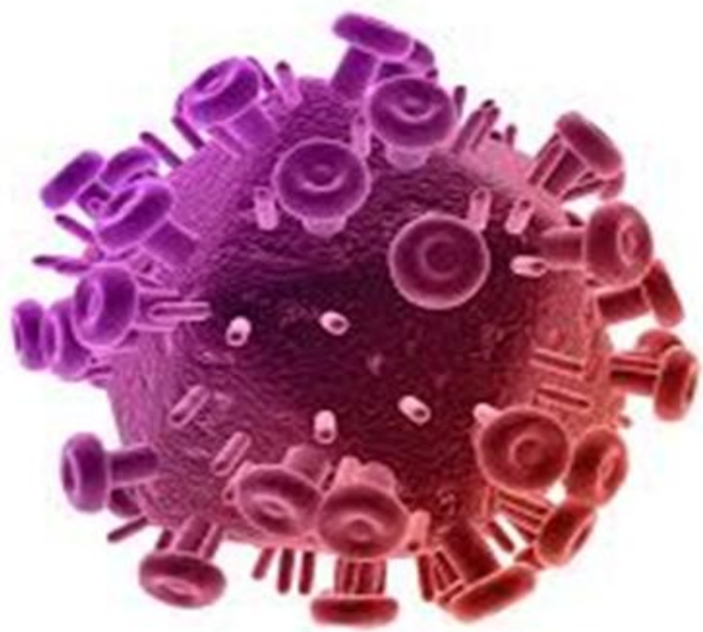
Kan bankacılığında dönüm noktalarından biri yaşandı. İlk defa Walter ve Murphy tarafından kanın toplanması için plastik torba tavsiye edildi. Dayanıklı plastik torbalar kanın toplanması ve saklanmasında kırılabilir ve saklanması zor cam şişenin yerini aldı. Böylece kanın toplanması ve sevkiyatı oldukça kolaylaştı.

Yıl: 1951



Bir laboratuvarda çalışan teknisyenin gliserol-albumin şişesine yanlışlıkla fruktoz yazması sonucu gliserolün soğuktan koruyucu etkisi keşfedildi. Tamamen rastlantıya dayalı bu keşif, kanın da gliserol yardımıyla saklanmasına olanak sağladı.

Yıl: 1981



İlk AİDS vakası bildirildi. İnsanlardan alınan kanın havuzlaştırılması, HIV (AİDS virüsü) gibi virüslerin kan nakli yapılan hastalarda görülmesine sebep oldu.

Yıl: 1985

Bağışçılardan alınan kanlarda HIV virüsü taranması zorunlu hale getirildi.

451

Yıl: 2004

Tüm dünyada olduğu gibi Türkiye'de de ABO kan grubu sistemini bulan Karl Landsteiner'in doğum günü olan 14 Haziran tarihi, Dünya Gönüllü Kan Bağışçıları Günü olarak kutlanmaya başlanmıştır.

Etkinlik 8

---Kan Nakil Zaman Çizelgesi---

Grup Adı______________________ Sınıf:_______________

Gruptaki Kişiler:____

1. Oluşturduğunuz zaman çizelgesinde bilimsel bilginin değiştiği ya da başka yöne doğru gittiğiyle ilgili bir kanıt bulabildiniz mi? Bulduysanız bunlar nelerdir?

2. Zaman çizelgenizde adı geçen bilim insanlarından aynı verilere sahip olmalarına rağmen farklı sonuçlar çıkaranlar var mı? Varsa hangi farklı çıkarımlarda bulunmuşlardır?

3. Sizce bilim insanlarının aynı verilerden farklı sonuçlar çıkarmasının nedenleri ne olabilir?

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____

4. Hazırladığınız zaman çizelgesinde çalışmasına kendi görüşlerini katan bilim insanı var mı? Eğer varsa kendi görüşlerini nasıl katmışlardır?

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APPENDIX N

N. WILLIAM HARVEY'S EXPERIMENTS

(W. HARVEY DENEYLERİ VİDEOSU)

Etkinlik 9

W. Harvey Deneyleri Videosu

İsim______________________ Sınıf:______________

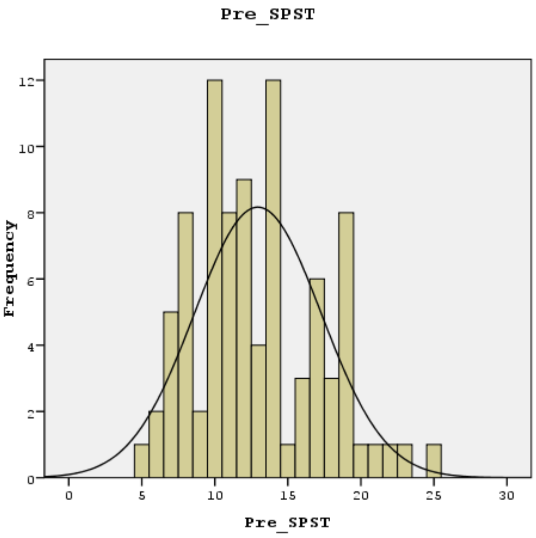
1. W. Harvey yeni bir dolaşım sistemini geliştirirken nasıl bir yol izledi?

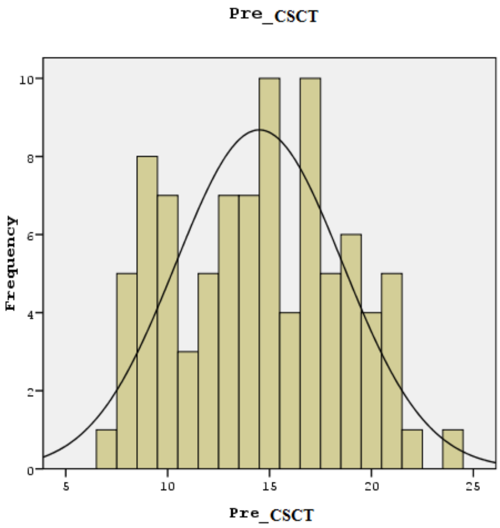
2. Harvey dolaşım sistemindeki bütün işlemleri gözlemleyebildi mi?

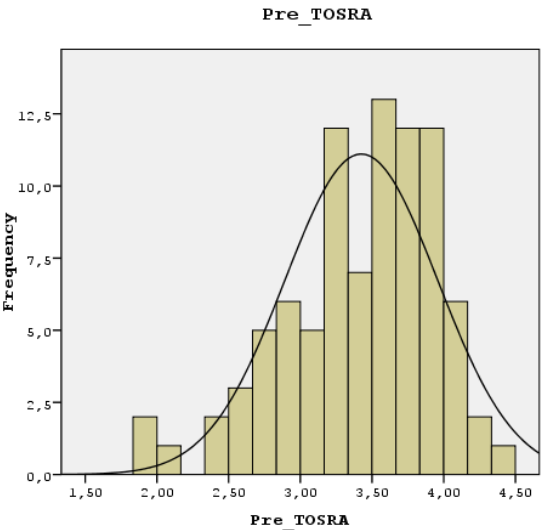
3. Harvey teorisini geliştirirken yaratıcılığını kullandığını düşünüyor musunuz? Cevabınız evet ise örnek veriniz.

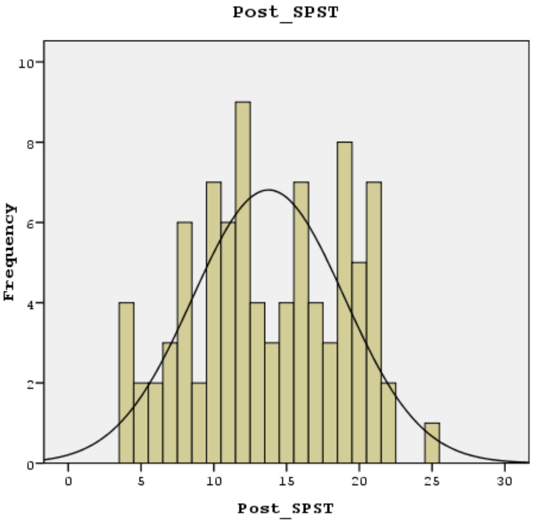
APPENDIX O

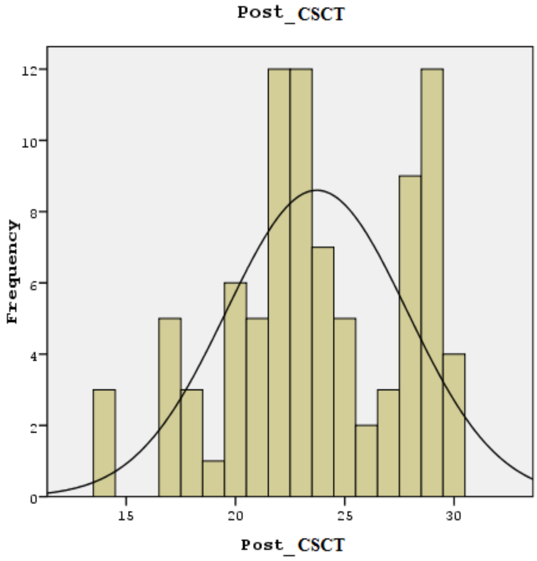
O. HISTOGRAMS SHOWING NORMALITY










Post_CSCT
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6
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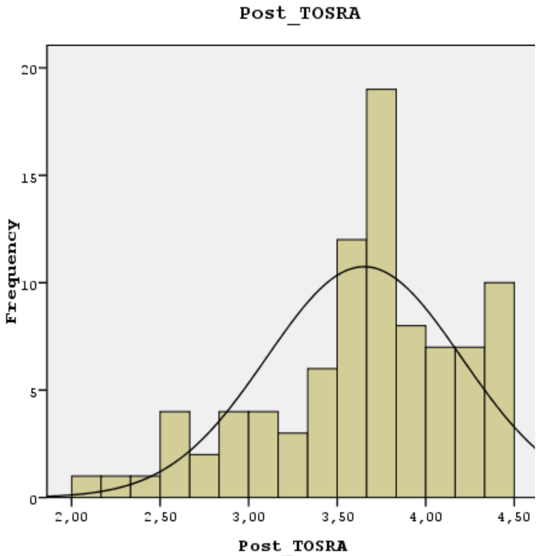
Post_CSCT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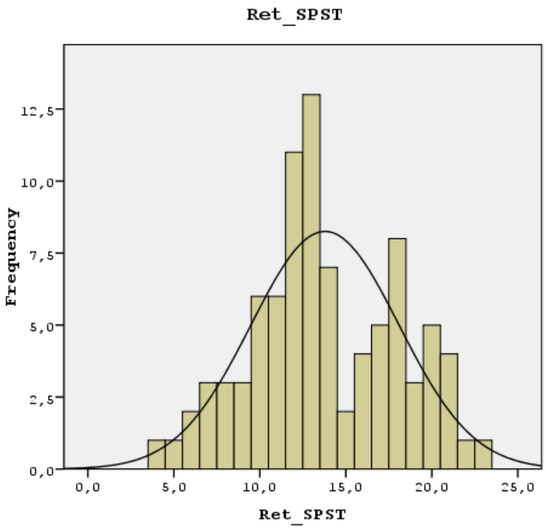
Post_TOSRA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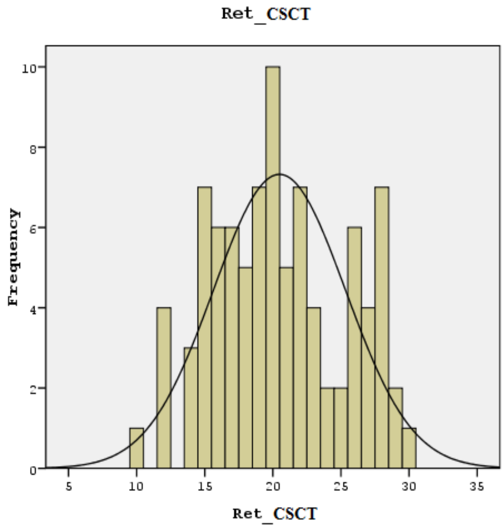
Ret_CSCT
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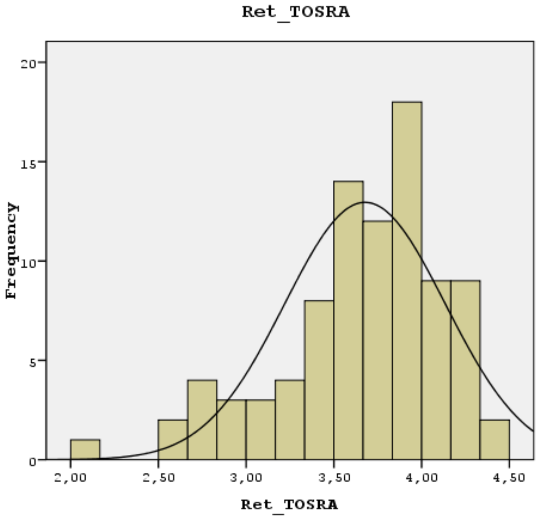
Ret_CSCT


Ret_TOSRA
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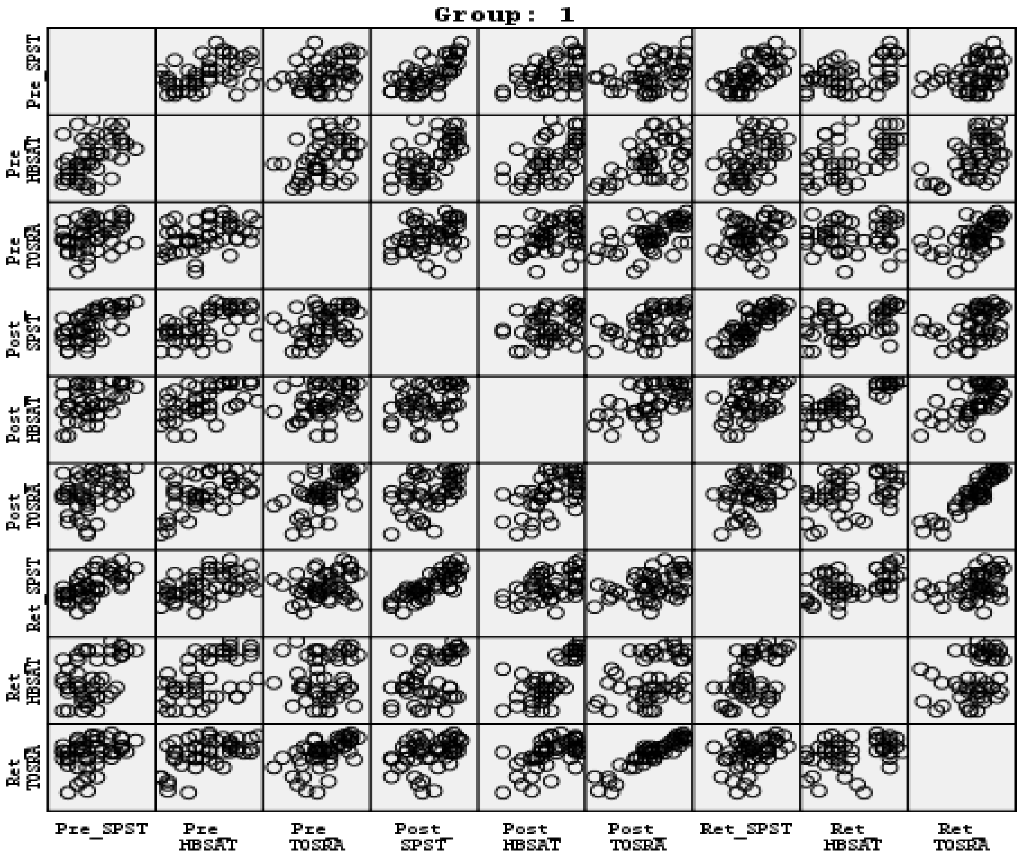
Ret_TOSRA

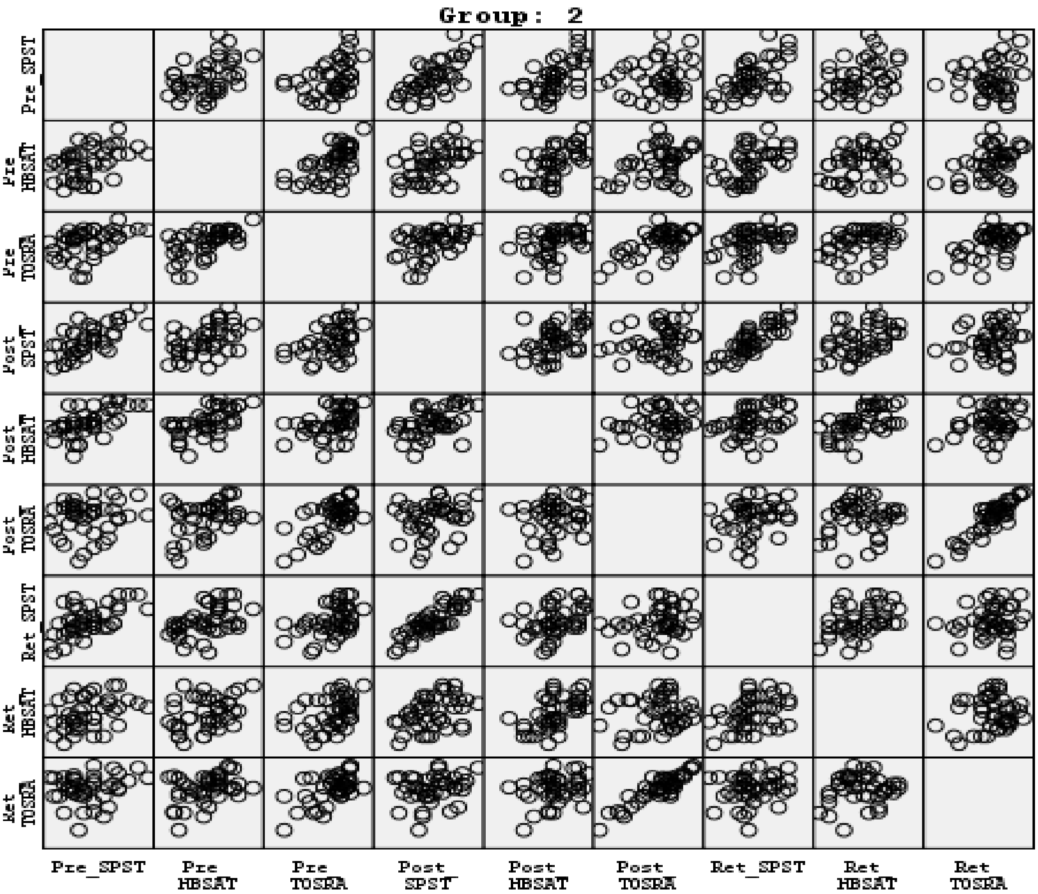
APPENDIX P

P. MATRIX SCATTERPLOTS FOR LINEARITY

Matrix Scatterplots for Experimental Group



Matrix Scatterplots for Comparison Group



APPENDIX R

R. ORIGINAL TURKISH TEXT OF SOME QUOTATIONS

1) Yapılan çalışmalar hipotezi destekliyorsa hipotezin yeterliliği ve geçerliliği artar. Eğer başka hipotezlerle de desteklenirse hipotez teoriye dönüşür. Teori, uzun bir sürecin ardından hiçbir itiraza ihtimal bırakmayacak şekilde evrenselleşir ve bir bilimsel gerçek şekline dönüşürse kanun halini alır (MEB, 2008, s. 9-4).

2) Bazı bilim insanları teorik çalışmaya yönelirken bazıları deneysel uygulamaya ağırlık verir. Bunların yanı sıra bazı bilim insanları teknolojik tasarımlarla daha fazla ilgilenir. Bu farklılıklara karşın, bilim insanlarının hepsi çalışmalarında bilimsel bir süreç izler. Öncelikle neyi aradıklarına karar verirler; ardından fikirlerini destekleyen kaynaklar toplar; gözlemler-deneyler yapar ve alternatif çözümler üretirler. (MEB, 2008, s. 9-2).

APPENDIX S

S. LEARNING OBJECTIVES OF CIRCULATORY SYSTEM

(Dolaşım Sistemi Kazanımları)

Dolaşım Sistemi ile ilgili olarak öğrenciler;

1. Dolaşım sistemini oluşturan yapı ve organları; model, levha ve/veya şema üzerinde gösterir.
2. Kalbin yapısı ve görevini açıklar.
3. Kan damarlarının çeşitlerini ve görevlerini belirtir.
4. Kanın yapısı ve görevlerini açıklar.
5. Büyük ve küçük kan dolaşımını şema üzerinde göstererek açıklar.
6. İnsanlarda farklı kan grupları olduğunu belirtir.
7. Kan bağışının insan vücudu ve toplum açısından önemini fark ederek yakın çevresini kan bağışında bulunmaya yönlendirir.
8. Lenfin dolaşım sisteminin öğesi olduğunu belirtir ve önemini açıklar.
9. Kalp ve damar sağlığını korumak amacıyla öneriler sunarak, bu konuda dikkatli davranır.
10. Teknolojik gelişmelerin dolaşım sistemi ile ilgili hastalıkların tedavisinde kullanımına örnekler verir.

APPENDIX T

T. EXTENDED TURKISH SUMMARY

(Genişletilmiş Türkçe Özet)

BİLİM TARİHİ EĞİTİMİNİN ORTAOKUL ÖĞRENCİLERİNİN FEN OKURYAZARLIĞINA ETKİSİ

Giriş ve İlgili Literatür

Günümüzde fen eğitimi araştırmacıları arasında yaygın olarak kabul edildiği gibi, fen eğitimini daha iyi bir noktaya taşımak için yapılan çabaların birçoğu fen okuryazarı bireyler yetiştirmek içindir; böylece fen eğitimi belli gruplar için değil toplumu oluşturan tüm bireyler için etkin hale gelir (Bybee, 1997; Feinstein, 2011; Millar, 2006; Roberts, 2007). Nitekim, Rutherford ve Ahlgren (1990) fen okuryazarlığının önemini vurgularken okulların temel işlevlerinin daha fazla fen içeriğini öğretmekten ziyade fen okuryazarlık için gerekli olana odaklanmasının gerekliliğini ifade etmiştir. Bugünün dünyasında bilim ve teknolojik değişimler ve gelişimler çok hızlı olduğu için fen okuryazar bireyler yetiştirmenin önemi bir kat daha artmıştır, çünkü Abd-El-Khalick ve BouJaoude'nin (1997) de vurguladığı gibi fen okuryazar bireyler temel bilimsel kavramları ve fen-teknoloji-toplum arasındaki ilişkiyi kolayca anlayabilir. Bunun farkında olan fen eğitimcileri, fen araştırmacıları ve Türkiye'de dahil birçok ülke tarafından fen okuryazar bireyler yetiştirmek eğitimin temel amaçlarından biri olarak kabul edilmiştir (Örneğin, BouJaoude, 2002; Milli Egitim Bakanligi [MEB], 2006; Zembylas, 2002).

Fen eğitimini geliştirmek için başta Amerika Birleşik Devletleri olmak üzere uluslararası ölçekte reform niteliğinde birçok projeler yapıldı (Örneğin Project 2000+, 1993; Project 2061, 1990; Science Literacy Project, 1999, 2005). Bu reform hareketlerinin ortak noktası nihai amacın fen okuryazarı bireyler yetiştirmek olarak konulmasıdır. Milli Eğitim Bakanlığı Fen Eğitimindeki bu uluslararası reform hareketlerine paralel olarak Türkiye'de eğitim alanında 2004 yılında yeniliğe gitmiş ve 2006 yılında mevcut Fen ve Teknoloji müfredatını uygulamaya koymuştur. Mevcut müfredatın vizyonu bireysel farklılıkları ne olursa olsun bütün öğrencilerin fen ve teknoloji okuryazarı olarak yetişmesidir (MEB, 2006).

Fen eğitimiyle ilgili literatür incelendiğinde, farklı çalışmalarda fen okuryazarlığının farklı bileşenlerine vurgu yapılmıştır. Örneğin Science for All Americans (AAAS, 1998) fen okuryazar bireylerin özelliği olarak temel fen kavramlarının anlamayı, bilimsel süreç becerilerine sahip olmayı, ve bilim, teknoloji ve toplum arasındaki etkileşimi kavramayı vurgulamıştır. Ayrıca, Abd-El-Khalick ve BouJaoude (1997) bilim-teknoloji-toplum arasındaki ilişkinin farkında olmayı, bilimsel süreçleri anlamayı, ve bilimin doğası anlayışını geliştirmeyi fen okuryazarlığının bileşenleri olarak vurguladı. Uluslararası Öğrenci Değerlendirme Programı (The Programme for International Student Assessment), 2003 yılında yapmış olduğu fen okuryazarlık tanımına 2006 yılında fene yönelik tutumu da ekleyip tanımını genişletti (OECD, 2006). Benzer şekilde Chin (2005) fene yönelik tutumu diğer üç bileşenle birlikte (alan bilgisi, bilim-teknoloji-toplum etkileşimi, bilimin doğası) fen okuryazarlığının ortak boyutu olarak vurguladı. Bu çalışmada yukarıda bahsedilen literatür ve ulusal fen müfredatı göz önünde bulundurularak fen okuryazarlığının dört bileşeni bilimsel süreç becerileri, temel fen kavramlarını anlama, fene yönelik tutum ve bilimin doğası görüşleri olarak belirlenmiştir.

Fen okuryazarlığının ilk bileşeni bilimsel süreç becerileridir. Lederman'a (2009) göre bilimsel süreç becerileri bilimsel araştırmayla (scientific inquiry) yakından ilişkilidir. Bu beceriler bilimsel kanıtları elde etmeye, yorumlamaya ve bu yönde hareket etmeye dayanır (OECD, 2006). Bilimsel süreç becerileri temel ve bütünleştirilmiş olarak ikiye ayrılır (Rezba, Sprague, McDonnough, and Matkins, 2007). Temel bilimsel süreç becerileri kişilere doğal dünyayı keşfetme olanağı sağlar. Bu beceriler gözlem yapmayı, tahminde bulunmayı, çıkarım yapmayı, sınıflama yapmayı, ölçüm almayı ve iletişim kurmayı içerir (Rezba ve diğ., 2007). Rebza ve meslektaşları bütünleştirilmiş süreç becerilerinin temel süreç becerilerine dayandığını, bütünleştirilmiş süreç becerilerine sahip olmanın öğrencilere fikirlerini çeşitli araştırmalar planlayarak test edebilme becerileri kazandıracağını vurguladı. Benzer şekilde Bailer, Ramig, and Ramsey (1995), bilimsel süreç becerilerine hakim olan öğrencilerin diğer öğrencilerden farklı olarak, en asgari düzeyde öğretmen yardımıyla bile, kendi seçtikleri konular üzerinde araştırmalar yapabilmesini mümkün kılacağını ifade etti. Bu nedenle öğretmenler, öğrencilerin sınıflarda bu becerileri geliştirmesine yardımcı olacak uygulamalar yapmalıdır.

Fen okuryazarlığının ikinci başlıca bileşeni temel fen kavramlarını anlamaktır. Temel fen kavramlarını anlamadan o kavramların ilişkili olduğu becerileri de sahip olmak olası değildir. Martin, Sexton, ve Franklin (2005) fen bilgisinin üç temel özelliklerini tutum, beceri ve fen kavramı olarak belirledi. Martin ve arkadaşları fen kavramlarının bilim insanlarının ortaya koyduğu ve topluma mal ettiği bilgileri içerdiğini ifade ettiler. Temel fen kavramlarını anlamak bilimsel okuryazar olmak açısından fen müfredatının en önemli hedeflerinden biridir (MEB, 2006). Bu yüzden de öğrenciler fen okuryazarı olmak için fen kavramlarıyla ilgili temel bir anlayışa sahip olmalıdır (AAAS, 1989; NRC, 1996; OECD, 2003).

Fen okuryazarlığının üçüncü bileşeni fene yönelik tutumdur. Koballa ve Crawley (1985) fene yönelik tutumu fen hakkında genel ve kalıcı pozitif veya negatif duygu olarak tanımlar. Bireylerin fene yönelik tutumları, bu fertlerin bilimsel araştırma yapmasında ayırt edici bir role sahip olabilir. OECD (2006) fen eğitiminin amaçlarından birinin fene yönelik tutumları geliştirmek olması gerektiğini; bu sayede öğrencilerin fene katılımının artacağını, ve bu kişilerin kişisel ve toplumsal sorumluluklarının gelişeceğini vurguladı. Bu sebeple araştırmacılar, öğrencilerin fene yönelik olumlu tutum geliştirmesi için farklı öğretim stratejileri üzerinde durdular; örneğin laboratuar uygulamaları (Freedman, 1997), yaratıcı drama (Hendrix, Eick, Shannon, 2012), tartışma-tabanlı eğitim (Çakır, 2011) ve bilim tarihi eğitimi (Kubli, 1999).

Fen okuryazarlığının son bileşeni bilimin doğası görüşüdür. Literatürde kabul gören tanıma göre bilimin doğası, bilimsel bilginin doğasında yer alan değer ve varsayımlardır (Lederman, 1992) ve ayrıca bilmenin bir yolu olarak ifade edilir (Lederman & Zeidler , 1986). Bilimin doğası fen okuryazar bireyleri yetiştirmek açısından fen eğitiminin kalıcı hedefi olarak birçok reform belgelerinde ve akademik çalışmalarda rastlanmaktadır (AAAS, 1989, 1993; Bell, Matkins ve Gansneder, 2011; Lederman, 1992; NRC, 1996). Lederman, Abd-El-Khalick, Bell, ve Schwartz (2002) özellikle üniversite öncesi eğitimde öğrencilerin erişmesi gereken bilimin doğası boyutlarını belirtmişlerdir. Bunlar; bilimsel bilginin değişebilir doğası, delile dayalı doğası, öznelliği, çıkarımsal yapısı, yaratıcılık ve hayal gücü içermesi, ve sosyal ve kültürel yapısıdır. Diğer üç ek boyut ise gözlem ve çıkarım arasındaki farklar, bilimde evrensel bir yöntemin olmaması, ve bilimsel teori ve kanunlar arasındaki ilişkiler ve bunarın işlevlerinin farkıdır (Abd-El-Khalick ve diğ., 2002). Öğrencilerin fen okuryazarı olmasının ön şartlarından biri bu boyutlardan yeterli bir anlayışa sahip olmasıdır. Bu nedenle öğrenciler bilimin doğası anlayışını geliştirmek için fen sınıflarında çeşitli uygulamalara dahil edilmelidir.

Fen okuryazarlığının yukarıda bahsedilen bileşenlerini geliştirmek için çeşitli uygulamalar hayata geçirilmiştir. Bilimsel süreç becerilerini geliştirmek için, örneğin, etkinlik temelli öğretim (Turpin, 2000); sorgulamaya dayalı öğretim (Yager ve Akçay, 2010); rehberli sorgulama (Köksal ve Berberoğlu, 2014; Yıldırım, 2012) ve yaratıcı-drama temelli öğretim (Taşkın-Can, 2013) gibi uygulamalardan yararlanılmıştır. Ayrıca, tartışma-tabanlı eğitim (Zohar ve Nemet, 2002); probleme dayalı öğrenme (Sungur, Tekkaya ve Geban, 2006); sosyobilimsel konu tabanlı eğitim (Klosterman ve Sadler, 2010); ve olaya dayalı öğrenme (Boz ve Uzuntiryaki, 2008) de dahil olmak üzere çeşitli öğretim yöntemlerinden, öğrencilerin temel fen kavramlarını anlamalarını teşvik etmek için yararlanılmıştır. Benzer şekilde, tartışma-tabanlı uygulama (Çakır, 2011); yaratıcı drama (Hendrix, Eick, ve Shannon, 2012); rehberli sorgulama (Köksal ve Berberoğlu, 2014); laboratuar uygulamaları (Freedman, 1997) gibi farklı yöntemler de bilime karşı öğrencilerin olumlu tutum geliştirmesi için kullanılmıştır. Son olarak açık-yansıtıcı etkinlik temelli öğretimin (Akerson, Abd-El-Khalick, ve Lederman, 2000; Çolak, 2009; Khishfe, 2008); deneysel fen programı (Jelinek, 1998); laboratuar etkinlikleri (McComas, 1993); jenerik aktiviteler (Lederman ve Abd-El-Khalick, 1998) öğrencilerin NOS görüşlerini geliştirmek için kullanılmıştır. Yukarıda sunulan fakat tam olmayan uygulama listesine ek olarak bilim tarihi eğitimi de fen okuryazarlığa ulaşmak için alternatif yöntem olarak fen araştırmacıları tarafından tavsiye edilmiştir (örneğin, Rutherford ve Ahlgren, 1990).

Fen eğitimindeki reform hareketleri, fen sınıflarında bilim tarihinden yararlanılması gerektiğinin altını çizdi (NRC, 1996). Kuhn (1970) öğrencilere bilimsel bilginin tarihsel süreçte nasıl ilerlediğinin verilmesi gerektiğini savundu ve buradan yola çıkarak bilim tarihinin fen müfredatının bir parçası olması gerektiğini tavsiye etti. Benzer şekilde fen müfredatına bilim tarihinin entegre edilmesinin bir ihtiyaç olduğu Proje 2061'de de aynı kararlılıkla vurgulandı (AAAS, 1989). Bilim tarihinin fen eğitiminde çok farklı yararlarının olduğu Matthews (1994) tarafından ortaya konmuştur. Bu yaraların bazıları temel fen kavramlarını anlamak, otantik öğrenme ortamları oluşturmak, muhakeme ve düşünme becerilerini geliştirmek, ve bilimi insancıllaştırarak fene karşı ilgi ve olumlu tutum geliştirmek olarak sıralanabilir (Matthews, 1994). Bu sebeplerden dolayıdır ki öğretmenler sınıflarında bilim tarihinden azami derecede yararlanmalıdır.

Bu çalışmanın amacı, bilim tarihi eğitimi ile müfredat tabanlı eğitimin altıncı sınıfta okuyan öğrencilerin fen okuryazarlığı üzerindeki karşılaştırmalı etkinliğinin araştırılmasıdır. Bu çalışmada fen okuryazarlığı, bilimsel süreç becerileri, dolaşım sistemi kavramların anlaşılması, fene karşı tutum ve bilimin doğası görüşleri olarak dört bileşen açısından incelenmiştir. Bu bağlamda çalışmanın ana ve yardımcı araştırma soruları aşağıdaki şekilde belirlenmiştir.

Ana Araştırma Sorusu:

Bilimsel süreç becerileri, dolaşım sistemi kavramların anlaşılması, fene karşı tutum ve bilimin doğası görüşleri üzerinde bilim tarihi eğitimi ve müfredat tabanlı eğitim üç test koşulu göze alındığında (ön test, son test, takip testi) hangi ölçüde farklı profiller oluşturmaktadır?

Yardımcı Araştırma Soruları:

1. Öğrencilerin bilimsel süreç becerilerini geliştirmede üç test koşulu göze alındığında bilim tarihi eğitimi müfredat tabanlı eğitimden hangi ölçüde daha etkilidir?

i. Bilimsel süreç beceriler açısından deney grubu ile karşılaştırma grubu arasındaki farklar ön test, son test, takip testinde sırasıyla nelerdir?

ii. Bilimsel süreç beceriler açısından her grubun kendi içindeki ön testten son teste; ve son testten takip testine olan değişimleri nasıldır?

2. Öğrencilerin dolaşım sistemi kavramlarının anlaşılmasını geliştirmede üç test koşulu göze alındığında bilim tarihi eğitimi müfredat tabanlı eğitimden hangi ölçüde daha etkilidir?

   i. Dolaşım sistemi kavramlarının anlaşılması açısından deney grubu ile karşılaştırma grubu arasındaki farklar ön test, son test, ve takip testinde sırasıyla nelerdir?

   ii. Dolaşım sistemi kavramlarının anlaşılması açısından her grubun kendi içindeki ön testten son teste; ve son testten takip testine olan değişimleri nasıldır?

3. Öğrencilerin fene karşı olumlu tutum geliştirmede üç test koşulu göze alındığında bilim tarihi eğitimi müfredat tabanlı eğitimden hangi ölçüde daha etkilidir?

   i. Fene karşı tutum açısından deney grubu ile karşılaştırma grubu arasındaki farklar ön test, son test, takip testinde sırasıyla nelerdir?

   ii. Fene karşı tutum açısından her grubun kendi içindeki ön testten son teste; ve son testten takip testine olan değişimleri nasıldır?

4. Öğrencilerin bilimin doğası görüşlerini geliştirmede üç test koşulu göze alındığında bilim tarihi eğitimi müfredat tabanlı eğitimden hangi ölçüde daha etkilidir?
    i. Bilimin doğası görüşleri açısından deney grubu ile karşılaştırma grubu arasındaki farklar ön test, son test, takip testinde sırasıyla nelerdir?
    ii. Bilimin doğası görüşleri açısından her grubun kendi içindeki ön testten son teste; ve son testten takip testine olan değişimleri nasıldır?

Yöntem

Bilim tarihi eğitimini müfredat tabanlı eğitimle karşılaştırmak için deneysel çalışma yöntemi kullanılmıştır. Deneysel çalışmanın doğasına uygun olarak bilim tarihi eğitiminin ve müfredat tabanlı eğitimin altıncı sınıf öğrencilerinin bilimsel süreç becerileri, dolaşım sistemi kavramlarının anlaşılması, fene karşı tutum ve bilimin doğası görüşleri üzerine etkisi araştırılmıştır. Öğrencilerin bu değişkenlere göre durumları ön test, son test ve takip testi olarak üç farklı zamanda ölçülmüştür. Çalışmanın deseni Tablo 1 de verilmiştir.

Tablo 1. Çalışmanın Deseni

	Deney Grubu	Karşılaştırma Grubu
Ön Test	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E
Uygulama	Bilim Tarihi Eğitimiyle Dolaşım Sistemi	Müfredat Tabanlı Eğitimle Dolaşım Sistemi
Son Test	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E
5 Haftalık Ara	Bilim Tarihi Olmaksızın Müfredat Tabanlı Eğitim	Bilim Tarihi Olmaksızın Müfredat Tabanlı Eğitim
Takip Testi	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E	Bilimsel Süreç Becerileri Testi Dolaşım Sistemi Kavram Testi Fen Tutum Testi Bilimin Doğası Ölçeği: FORM-E

Evren ve Örneklem

Bu çalışmanın hedef evrenini, Ankara'da kamu okullarında okuyan tüm altıncı sınıf ortaokul öğrencileri oluşturmaktadır. Erişilebilir evrenini ise Ankara'nın Çankaya ilçesindeki devlet okullarında eğitim gören tüm altıncı sınıf öğrencileri oluşturmaktadır. Bu çalışmanın örneklemini toplamda 95 öğrenci (47 erkek, 48 kadın) oluşturmaktadır. Kırk dört öğrenci karşılaştırma grubunda iken, 51 öğrenci deney grubunda yer aldı. Öğrencilerin özgeçmişleri incelendiğinde birbirine benzer sosyal çevreden geldiği görülmektedir.

Veri Toplama Araçları

Bu çalışmanın verileri Bilimsel Süreç Becerileri Testi, Dolaşım Sistemi Kavram Testi, Fen Tutum Testi ve Bilimin Doğası Ölçeği: FORM-E kullanılarak toplanmıştır.

Bilimsel Süreç Becerileri Testi: Bu test ilk olarak Burns, Okey ve Wise (1985) tarafından geliştirilmiştir. Öğrencilerin bilimsel süreç becerilerini, değişkenleri belirleme, hipotez kurma, işlemsel tanımlama, veri grafiği ve yorumlanması, ve araştırma tasarımı açılarından ölçmeyi hedeflemiştir. Burns ve ark. (1985) bu testin sonuçlarını her doğru cevaba 1 puan ve yer yanlış cevaba 0 puan vererek değerlendirmişlerdir. Diğer bir deyişle bir öğrencinin bu testin orijinalinden alacağı puan 0-36 arasında değişmektedir. Bilimsel Süreç Becerileri Testi İngilizceden Türkçeye ilk olarak Geban, Aşkar and Özkan (1992) tarafından dokuzuncu sınıf öğrencileri baz alınarak çevrilmiş ve gerekli güvenilirlik ve geçerlilik kanıtları sağlanmıştır. Daha sonra Can (2008) bu testin geçerlilik ve güvenilirlik çalışmasını ortaokul yedinci sınıf öğrencileriyle yapmış, ve 26 maddenin bu seviye öğrencileriyle çalıştığını ortaya çıkarmıştır. Bu çalışmada da Bilimsel Süreç Becerileri Testi'nin 26 maddelik versiyonunun öğrencilerin seviyesi için daha uygun olduğu kararlaştırılmıştır.

Dolaşım Sistemi Kavram Testi: Bu test araştırmacı tarafından geliştirilmiştir. Araştırmacı bu testi geliştirirken, dolaşım sistemi konusundaki altıncı sınıf fen ve teknoloji müfredatında belirtilen kazanımlar göz önünde bulundurmuştur. Bu testi geliştirirken ilk olarak 32 çoktan seçmeli sorudan oluşan bir madde havuzu oluşturuldu. Daha sonra fen eğitiminden iki uzman öğretim üyesi bu maddeleri teker teker inceleyip, görüş belirtti. Ardından uzman görüşü paralelinde sorular tekrar düzenlendi. Bir sonraki süreçte sorular, tıpta uzman bir doktor tarafından incelenip görüş alındı. Tekrar gerekli düzenlemeler yapıldı. Testin bu form tekrar uzmanları ile müzakere edilmiştir ve ekip arasında fikir birliği sağlanarak test hazır hale getirilmiştir. Bir sonraki basamakta test, Türkçe öğretmeni tarafından incelenmiş ve olası anlatım bozuklukları giderilmiştir. Testin bu hali bir sonraki adımda altıncı sınıftan dört öğrenciyle görüşme yapılıp, bu öğrencilere testi alması sağlandırılmıştır. Bu süreçte testin altıncı sınıf öğrencilerinin seviyesi için uygun olduğu ve testi ortalama olarak 30-35 dakikada tamamlayabildikleri tespit edilmiştir. Daha sonra test 135 öğrenciye pilot olarak uygulanmış ve geçerlilik katsayısı .74 olarak bulunmuştur.

Fen Tutum Testi: Bu testin ilk olarak Fraser (1978) tarafından geliştirilmiştir. Orijinal test toplamda 7 alt boyut ve 70 maddeden oluşmaktadır. Fraser bu testin geçerlilik ve güvenilirlik çalışmasını 7, 8, 9 ve 10. sınıflar için yapmıştır. Bu test Telli, Çakıroğlu, ve Rakıcı (2003) tarafından, dokuzuncu ve onuncu sınıf öğrencileriyle Türkçeye adapte edilmiştir. Bu çalışmada öğrencilerin seviyeleri göz önünde bulundurularak, Fen Tutum Testi'nin yalnızca dört boyutu kullanılmaya karar verilmiştir. Bu dört boyutu oluşturan maddeler altıncı sınıftan 8 öğrenciyle görüşme yapılmış ve öğrencilerin maddeleri anlamasında herhangi bir sorun gözlemlenmemiştir. Bir sonraki adımda bu test 217 altıncı sınıf öğrencisine uygulanmıştır ve bu dört boyut faktör analizle uygunluğu test edilmiştir. Faktör analiz sonucu testin bu halinin dört faktörlü yapıya uymadığı, fakat 5. ve 29. maddeler çıkarıldığında tek faktör altında toplandığı görülmüştür. Bu sebepten dolayı Fen Tutum Testinde 5. ve 29 maddeler çıkartılıp tek faktör olarak analiz edilmiştir.

Bilimin Doğası Ölçeği: FORM-E: Katılımcıların bilimin doğası ile ilgili görüşlerini ölçmek için Lederman ve Ko (2004) tarafından geliştirilen ve toplamda 7 açık uçlu sorudan oluşan bu ölçek kullanılmıştır. Lederman (2007) bu ölçeğin ilköğretim öğrencileri için gelişimsel ve dil açılarından uygun olduğunu belirtmiş, bu yüzden bu çalışmada bu ölçekten yararlanılmıştır. Bilimin Doğası Ölçeği: FORM-E, bilimsel bilginin değişebilir doğası, öznelliği, delile dayalı doğası, yaratıcılık ve hayal gücü içermesi, ve çıkarımsal yapısı olmak üzere toplamda beş temel bilimin doğası boyutunu ölçmektedir. Bu ölçek Doğan, Çakıroğlu, Çavuş and Bilican (2010) tarafından Türkçeye çevrilmiş ve geçerliliği sağlanmıştır.

Uygulama

Bu çalışma kapsamında yapılan uygulamada, amaçla paralel olarak, deney grubu öğrencileri dolaşım sistemi konusunu müfredata bilim tarihiyle ilgili aktiviteler entegre edilerek öğrenmiş olup; karşılaştırma grubu ise müfredat tabanlı eğitimle aynı konuyu işlemiştir. Birçok çalışma fen öğretmenlerinin yeterli bilimin doğası anlayışına sahip olsalar dahi çoğu kez öğrencilerine bilimin doğası boyutlarını öğretmelerinin mümkün olmadığını; ya da bunu öğretmek için yeteri düzeyde motive olamadıklarını göstermiştir (Akerson ve Abd-El-Khalick, 2003; Akerson, ve Hanuscin, 2007; Bell ve diğ., 2000; Hodson, 1993; Lederman, 1999). Ayrıca çalışmanın yapıldığı sınıfların fen bilgisi öğretmeni bilim tarihinde yeterli olamayacağını çalışma başlangıcında açıkça belirtmiştir. Bu yüzden, uygulama boyunca deney grubu öğrencilerine dersler araştırmacı tarafından verilmiş olup, karşılaştırma grubuna dersleri kendi fen öğretmenleri vermiştir. Uygulama boyunca ortaya çıkabilecek olası uygulama tehdidine çözüm olarak öğretmen ve araştırmacı her ders öncesi görüşüp konuyla ilgili ders planı hazırlamışlardır. Böylece iki grupta da benzer sırada ve benzer konu-temelli aktiviteler uygulanması sağlanmıştır. Ayrıca araştırmacı ve öğretmen süreç boyunca birbirlerinin derslerini gözlemleyerek hazırlanan ders planının dışına çıkılmaması sağlandı. Her dersin sonunda araştırmacı ve öğretmen iki grupta yapılan derslerin birbirlerine benzerliğini müzakere etti. Bu yapılanlar iki grup arasında oldukça benzer uygulamalar yapıldığıyla ilgili kanıt sağladı.

Uygulama öncesinde araştırmacı, dört haftalık bir ön hazırlık çalışması yapmıştır. Bu ön hazırlık çalışmanın asıl amacı gruplar arasında ortaya çıkabilecek farkların yeni bir öğretmene bağlı olma ihtimalini minimuma indirme düşüncesiydi. Bu ön çalışmaların ilk haftasında araştırmacı fen bilgisi öğretmenini gözlemleyerek bazı yararlı bilgiler elde etmeye çalıştı; örneğin, sınıftaki öğrencilerin isimleri, öğretmenin konuları anlatış biçim, öğretmenin sınıf yönetimi stratejileri gibi. Geri kalan üç haftada araştırmacı deney grubunda dersleri anlatarak sınıftaki öğrencilere alışmaya çalıştı. Yine bu süre zarfında araştırmacı ile öğretmen birbirlerini gözlemleyerek, sınıf içi uygulamaları olabildiğince eşitlemeye çalışmıştır. Bu dört haftalık ön hazırlık çalışması sırasında araştırmacı; öğrencilere aşina olma, sınıf kuralları ve rutinleri gözlemleme, öğrenci-öğretmen ve öğrencilerin birbirleriyle iletişim biçimini öğrenme, sınıf ortamını alışma, ve en önemlisi de öğretmenle öğretim şeklini uyumlu hale getirme şansı bulmuştur. Ayriyeten, bu ön hazırlık çalışmasının üçüncü ve dördüncü haftasında öğrencilere ön testler de uygulanmıştır.

Dört haftalık ön hazırlık çalışmasının ardından her iki grupta da uygulamalara başlanmıştır. Bu süreçte iki grupta müfredatta önerilen beş temel etkinlik uygulanmıştır. Her etkinlik öncesi sadece deney grubu bilim tarihiyle ilgili çeşitli aktivitelere katılmıştır. Aktivitelerin kısa halleri aşağıdaki gibidir.

Tarihsel kısa hikâye 1 (Sadece deney grubu): Bilimsel makalelerden derlenen bu hikâyede kalp, farklı toplum ve farklı bilim insanları tarafından ne düzeyde farklı anlaşıldığını göstermek için hazırlanmıştır. Bu hikâye ile öğrencilerin arasındaki genel yargı olan *bilimsel bilginin kesin ve değişmez olduğunu* görüşünün yanlışlığının farkına varması amaçlanmıştır.

Kalbin yapısı ve görevleri (Her iki grup): Bu aktivitede öğrenciler beşerli gruplar oluşturarak gerçek koyun kalbini incelediler. Bu aktivite süresince öğrenciler kalbin dış yapısını, kalbin iç yapısını ve kısımlarını incelediler. Bu aktiviteyle öğrenciler bilimsel süreç becerilerinden gözlem, çıkarım ve gözlemleri not etmeyi geliştirilmesi de ayrıca amaçlanmıştır.

Tarihsel kısa hikâye 2 (Sadece deney grubu): Bu hikayedeki ana vurgu mikroskobun icadıyla kanın yapısı hakkındaki bilimsel bilginin farklı bir yön aldığını vurgulamaktı. Mikroskobun icadından sonra özellikle kanın yapısıyla ilgili daha güvenilir bilgiler elde edildiği, ve bu alandaki bilgi birikimin arttığı vurgulanarak bilimin doğasıyla ilgili *delile dayalı doğası* boyutu keşfedilmeye çalışılmıştır.

Kanı oluşturan yapılar ve görevleri (Her iki grup): Bu aktivitenin amacı kanın yapısında hem plazma hem de kan hücreleri bulunduğunu öğrencilerin dikkatine sunmaktır. Bu aktivitede bilimsel süreç becerilerinden gözlem yapma, iletişim kurabilme ve çıkarım yapma becerilerinin geliştirilmesi amaçlanmaktadır. Öğrenciler aktivitede mikroskop altında hazır preparatları incelediler, ayrıca mikroskobu nasıl kullanacaklarıyla ilgili temel bilgiler de öğrencilere öğretilmiştir.

Tarihsel kısa hikâye 3 (Sadece deney grubu): Bu aktivite diğerleriyle kıyaslandığında daha geniş kapsamlı bir aktivitedir. Bu aktiviteyle öğrencilere özellikle vurgulanmak istenen bilimin doğası boyutları bilimsel bilginin öznelliği, bilimsel bilginin değişebilir doğası, ve bilimde tek yöntemin olmadığıdır. Aktivitede ayrıca bilimin doğası boyutlarından bilimin yaratıcılık ve hayal gücü içermesi ve delile dayalı doğası da vurgulanmıştır. Bu hikayedeki temel noktalardan bazıları Galen'in dolaşım sistemi fizyolojisi, bu fizyolojinin neredeyse tamamen yanlış olmasına rağmen 16 yüzyıl nasıl ayakta durabildiği, Harvey'in dolaşım sistemini nasıl keşfettiği ve bu sırada hangi yöntemleri kullandığıdır.

Küçük ve büyük kan dolaşımı (Her iki grup): Bu aktivite iki kısımdan oluşmaktadır. İlk kısımda öğrencilere küçük ve büyük kan dolaşımıyla ilgili model geliştirmelerini sağlanıp, ikinci kısımda küçük ve büyük kan dolaşımıyla ilgili sınıf içi oyun etkinliği yaptırılmıştır. Bu iki aktivitede ve konu sürecinde öğrencilere sağlanan bilgiler sayesinde öğrencilerin damar çeşitlerini, kanın küçük ve büyük kan dolaşımında izlediği yolu, ve bu iki dolaşım arasındaki ilişkiyi kavraması hedeflenmiştir.

Kan nakil tarihi zaman çizelgesi (Sadece deney grubu): Bu aktivitenin isminden de anlaşılacağı gibi öğrencilere kan naklindeki gelişimler hakkında zaman çizelgesi hazırlatılmıştır. Bu aktiviteyle amaçlanan; öğrenciler bilimdeki değişimlerin farkına varması, bilimde gözlem ve deneyin kilit rolünü kavraması, bilimsel bilginin gelişmesinde yaratıcılığın ve hayal gücünün önemini anlaması, ve aynı bilgiye bakarak farklı yorumların olacağını; yani diğer bir deyişle bilimde öznelliğin farkına varmasıdır.

Kan grupları (Her iki grup): Bu aktivite sayesinde öğrencilerden beklenen insanlarda farklı kan gruplarının olduğunu kavraması, her grubun da birbirleriyle kan alış-verişi yapamayacağını içselleştirmesidir. İlâveten öğrencilerden veri toplama, grafik oluşturma, grafiği yorumlama, ve iletişim kurma becerilerini de geliştirmesi beklenmektedir.

William Harvey Deneyleri (Sadece deney grubu): Bu etkiliğin amacı deney grubu öğrencilerinin bilimin doğasının boyutlarından olan bilimin delile dayalı doğası ve yaratıcılık ve hayal gücü içermesi açısından açık ve yansıtıcı bir tartışma ortamı yaratmaktır. Bu aktivitede öğrenciler Harvey'in çalışmalarıyla ilgili video izlediler. Bu videoda Harvey'in dolaşım sistemini ortaya koyarken yapmış olduğu deneylerin bir tekrarını izlediler.

Kan bağışı (Her iki grup): Bu aktivite kan bağışının önemini vurgulamak için hazırlanmış ve öğrencilerin kan bağışına karşı bir sağduyu geliştirmeleri amaçlanmıştır. Bu aktivitede öğrenciler dört gruba ayrılarak her bir gruba yaratıcı drama hazırlayıp sınıf önünde sergilemeleriyle ilgili konular dağıtılmıştır. Her bir gruba dağıtılan konular farklı olmasına rağmen her birinin ortak yanı kan bağışının çeşitli kişi ve kurumlara olan faydasıyla ilgili olmasıydı. Etkinliğin sonunda öğrencilere dolaşım sistemi sağlığının önemi, ve bu sağlığın korunmasında yapılması ve yapılmaması gerekenlerle ilgili bir sunum yapılmıştır.

Bütün aktiviteler bittikten sonra öğrencilere son test olarak Bilimsel Süreç Becerileri Testi, Dolaşım Sistemi Kavram Testi, Fen Tutum Testi, ve Bilimin Doğası Ölçeği: FORM-E uygulanmıştır.

Uygulamayı takip eden 5 hafta iki gruptaki öğrenciler de müfredat tabanlı eğitimle öğrenimlerine devam etmişler, ve bilim tarihi ile ilgili herhangi bir uygulama almamışlardır. Bu beş haftalık aranın sonunda iki gruptaki öğrencilere de yukarıda bahsedilen testler takip testi olarak tekrar uygulanmıştır.

Sonuçlar ve Tartışma

Bu bölümde ilk olarak bilimsel süreç becerileri, dolaşım sistemi kavramların anlaşılması, ve fene karşı tutum açısından gruplar arasında fark olup olmadığı Tek-Yönlü MANOVA kullanılarak analiz edilmiştir. Bu test için gerekli olan varsayımlar test edilmiş ve testi uygulamak için gereken varsayımlara aksi bir durum rastlanmamıştır. Wilks' Lambda kriterine göre deney grubu ile karşılaştırma grubu arasında, çalışma öncesinde anlamlı bir fark bulunamamıştır, F (3, 89) = .29, p = .832, Wilks' Lambda = .99. Bu sonuç, bilimsel süreç becerileri, dolaşım sistemi kavramlarının anlaşılması ve fene karşı tutum açısından deney ve karşılaştırma grupları arasında önceden var olan bir fark olmadığını göstermiştir.

Bir sonraki adımda grupların üç ölçüm sürecinde bilimsel süreç becerileri, dolaşım sistemi kavramlarının anlaşılması ve fene karşı tutum açısından ortaya çıkardıkları profilleri karşılaştırmak için Profil Analizin özel bir türevi olan Tekrarlanan Ölçümlü MANOVA (Repeated-Measures MANOVA) kullanılmıştır. Bu analizin varsayımlarının detaylı analizi yapılmış ve varsayımlarını ihlal edecek önemli bir kanıta rastlanmamıştır. Analiz sonuçları incelendiğinde paralellik testi istatistiksel olarak anlamlı bulunmuştur, multivariate F (6, 81) = 4.17, p = .001, Wilks' Lambda = .76, partial η^2 = .24. Bu sonuç bize grupların bağımlı değişkenleri ortak olarak düşünüldüğünde iki grubun zamana göre oluşturdukları profillerin anlamlı derecede farklı olduğunu gösterir. Bu sonuç, çalışmanın değişkenleri açısından düşünüldüğünde, bilim tarihi eğitimi ve müfredat tabanlı eğitimin fen okuryazarlığının üç temel bilenleşenleri açısından farklı kazanımlar ortaya koyduğunu işaret etmektedir.

Tabachnick ve Fidell (2012) grupların profillerinin istatistiksel olarak anlamlı şekilde birbirlerinden farklı olduğu durumlarda, basit etkiler analiziyle (simple-effect analysis) her bir bağımlı değişkenin ayrı ayrı incelenmesinin gerektiğini tavsiye etmiştir. Bu yüzden gruplar, her bir bağımlı değişken açısından ayrı ayrı analiz edilmişlerdir.

Bilimsel Süreç Becerileri:

Deney ve karşılaştırma gruplarının Bilimsel Süreç Becerileri Testi'nden ön test, son test ve takip testinde aldıkları puanlar, karma faktörlü ANOVA (Mixed-ANOVA) ile analiz edilmiştir. Bütün varsayımlar sağlandıktan sonra, analiz sonucu istatistiksel olarak anlamlı bir etkileşim etkisinin (interaction effect) olmadığını göstermiştir, Wilks λ = .95, F (2, 85) = .09, p = .912. Benzer şekilde gruplar arasındaki temel etki, F (1, 86) = .03, p = .86; ve zamana göre temel etki, Wilks λ = .95, F (2, 85) = 2.13, p = .125 istatistiksel olarak birbirinden farklı çıkmamıştır. Bu sonuç bize bilimsel süreç becerilerini geliştirmek açısından birbirlerine göre anlamlı bir üstünlüğünün olduğuyla ilgili yeterli kanıt bulunamadığını göstermektedir. Bu sonuca dayanarak, bilim tarihi eğitimi ile müfredat tabanlı eğitimin zamana göre öğrencilerin Bilimsel Süreç Becerileri Testi puanlarında benzer bir değişime sebep olduğunu iddia etmek de mümkündür. Tablo 2, grupların Bilimsel Süreç Becerileri Testi'nde aldıkları ortalama puanları yansıtmaktadır.

Tablo 2. Grupların Ortalama Bilimsel Süreç Becerileri Testi Puanları

	Deney Grubu			Karşılaştırma grubu		
	n	M	SD	n	M	SD
BSBT* (Ön test)	47	13.02	4.01	41	12.98	4.74
BSBT (Son test)	47	13.94	5.34	41	13.61	5.19
BSBT (Takip testi)	47	13.87	4.56	41	13.78	4.05

BSBT kısaltması, Bilimsel Süreç Becerileri Testi için kullanılmıştır.

Dolaşım Sistemi Kavramlarının Anlaşılması:

Karma faktörlü ANOVA sonucuna göre, iki grup arasında Dolaşım Sistemi Kavram Testi açısından istatistiksel olarak anlamlı bir etkileşim etkisi vardır, Wilks $\lambda = .82$, F (2, 85) = 9.44, $p < .0005$. Bu sonuç, bilim tarihi eğitimi alan grup ile müfredat tabanlı eğitim alan grubun, Dolaşım Sistemi Kavram Testi'nden üç zaman diliminde aldıkları puanlarının değişiminin farklı olduğunu göstermektedir. İki grubun bu testten aldıkları puanlara göre çizdikleri profiller incelendiğinde, ön testten takip testine doğru gidildikçe, puanlar arasındaki farkın, bilim tarihi grubu lehine, açıldığı gözlemlenmektedir. İki grubun aldıkları puanlar bağımsız gruplar t-test (independent samples t-test) yöntemiyle karşılaştırıldığında, son testte deney grubunun (M = 24.30, SD = 4.19) karşılaştırma grubuna (M = 23.29, SD = 3.79) göre benzer ortalamalar aldığı gözlemlenmiştir t (86) = 1.17; p = .244. Diğer taraftan, deney grubunun takip testinden aldığı puanların ortalaması (M = 22.17, SD = 4.72), karşılaştırma grubundan (M = 18.46, SD = 4.28) anlamlı şekilde yüksektir, t (86) = 3.84; $p < .0005$. Bu sonuca göre bilim tarihi eğitiminin, müfredat tabanlı eğitimden, dolaşım sistemi kavramlarını hafızada tutma açısından daha etkin olduğu sonucuna varılabilir. Tablo 3'de iki grubun Dolaşım Sistemi Kavram Testi'nden aldıkları puanlar verilmiştir.

Tablo 3. Grupların Ortalama Dolaşım Sistemi Kavram Testi Puanları

	Deney Grubu			Karşılaştırma grubu		
	n	M	SD	n	M	SD
DSKT* (Ön test)	47	14.47	3.93	41	14.59	4.34
DSKT (Son test)	47	24.30	4.19	41	23.29	3.79
DSKT (Takip testi)	47	22.17	4.72	41	18.46	4.28

DSKT kısaltması, Dolaşım Sistemi Kavram Testi için kullanılmıştır.

Fene Karşı Tutum:

Öğrencilerin çalışma boyunca gösterdikleri fen tutumları Karma faktörlü ANOVA istatistiksel yöntemi kullanılarak analiz edilmiştir. Analiz sonucu istatistiksel olarak anlamlı bir etkileşim etkisi olduğunu ortaya koymuştur, Wilks λ = .93, F (2, 85) = 3.32, p = .041. Bu sonuç, iki grubun üç zaman diliminde fene karşı sergiledikleri tutumların farklı olduğu anlamına gelmektedir. İki grubun bu testten aldıkları puanlara göre çizdikleri profiller incelendiğinde her iki grubunda son test puanlarında, ön testten aldıkları puanlarla karşılaştırıldığında, bir artış olduğu gözlemlenmiş; fakat bu artışın deney grubu için çok daha belirgin olduğu gözlemlenmiştir.

İki grubun Fen Tutum Testi'nin aldıkları puanlar bağımsız gruplar t-test yöntemiyle karşılaştırıldığında, deney grubunun son testten aldığı ortalama puanının (M = 3.80, SD = .49) karşılaştırma grubunun ortalama puanıyla (M = 3.51, SD = .57) karşılaştırıldığında, deney grubunun puanının anlamlı oranda yüksek olduğu bulunmuştur. Bu sonuç bize bilim tarihi eğitimi alan öğrencilerin müfredat tabanlı eğitim alan öğrencilere göre uygulamaların hemen ardından daha olumlu bir tutum sergilediğini göstermiştir.

Benzer şekilde grupların uygulamadan beş hafta sonra Fen Tutum Testi'nden aldıkları puanlar karşılaştırıldığında deney grubunun puanının (*M* = 3.80, *SD* = .39) karşılaştırma grubunun puanında (*M* = 3.57, *SD* = .48) anlamlı şekilde yüksek olduğu görülmüştür. Genel olarak bu bulgu, deney grubu öğrencilerinin sahip oldukları tutumun karşılaştırma grubu öğrencilerine göre, uygulamalardan beş hafta sonrasında bile daha olumlu olduğunu ortaya koymuştur. Bu sonuçlara göre bilim tarihi eğitiminin fene karşı olumlu tutum geliştirme ve olumlu tutumu sürdürme açısından müfredat tabanlı eğitimden daha etkin olduğu sonucuna varılabilir. Tablo 4'de iki grubun Fen Tutum Testi'nden aldıkları puanlar verilmiştir.

Tablo 4. Grupların Ortalama Fen Tutum Testi Puanları

	Deney Grubu			Karşılaştırma grubu		
	n	M	SD	n	M	SD
FTT* (Ön test)	47	3.45	.52	41	3.41	.56
FTT (Son test)	47	3.80	.49	41	3.51	.57
FTT (Takip testi)	47	3.80	.39	41	3.57	.48

FTT kısaltması, Fen Tutum Testi için kullanılmıştır.

Bilimin Doğası Görüşleri:

Bu çalışma boyunca öğrencilerin bilimin doğası ile ilgili görüşleri, daha önce de bahsedildiği gibi, Bilimin Doğası Ölçeği: FORM-E kullanılarak elde edilmiştir. Çalışmada öğrencilerin adı geçen ölçeğe vermiş olduğu cevaplar hem nicel hem de nitel olarak incelenmiştir. Katılımcılarından elde edilen görüşler çalışma sürecinde geliştirilen bir puanlama anahtarı (rubric) ile değerlendirilmiştir. Bu puanlama anahtarı geliştirilirken bilimin doğası alanında uzman bağımsız bir araştırmacı ile çalışılmış ve kodlar üzerinde uzlaşma sağlanmıştır. Bu puanlama anahtarında öğrencilerin görüşleri "yetersiz" (naïve), "değişken" (transitional), ve "bilgili" (informed) olarak üç ana kategori altında gruplandırılmıştır. Çalışma sürecinde öğrencilerin bilimin doğası görüşlerinde geliştirilmesi hedeflenen boyutlar: *bilimsel bilginin değişebilir doğası, öznelliği, delile dayalı doğası, yaratıcılık ve hayal gücü içermesi, ve çıkarımsal yapısı* şeklindedir. Burada bahsedilmesi gerek önemli noktalardan biri de öğrencilerin Bilimin Doğası Ölçeği: FORM-E ye verdiği cevapları analiz ederken kullanılan "bütünsellik" yaklaşımıdır. Bu yaklaşımda, diğer araştırmacılar tarafından da tavsiye edilen (örn. Khishfe ve Abd-El-Khalick, 2002); Lederman ve diğ., 2002) ve öğrencilerin görüşlerini her bir maddeye verdiği cevapla bir bilimin doğası boyutunu değerlendirmek yerine, ölçeğin bütününde verdiği cevaplar göz önüne alınarak değerlendirilmiştir.

Bilimsel Bilginin Değişebilir Doğası:

Her bir kategorideki (yetersiz, değişken, bilgili) öğrenci sayılarının ön testten son teste ve son testten takip testine değişimi, McNemar Testi ile istatistiksel olarak karşılaştırıldı. Deney grubunda, bilimsel bilginin değişebilir doğası ile ilgili yetersiz görüşe sahip olan kişilerin oranı ön testten (% 52) son tests (% 29) istatistiksel olarak anlamlı bir şekilde azaldığı gözlemlendi, χ^2 = 5.88, p =.013. Diğer taraftan, bu gruptaki değişken ve bilgili görüşe sahip kişilerin oranında bir artış olmasına rağmen, bu artış istatistiksel olarak anlamlı bir farka sebep olmadı.

Yine deney grubunda öğrencilerin görüşlerinde kategori bazında bir değişim gözlenmemiştir. Karşılaştırma grubunun bilimsel bilginin değişebilir yapısı ile ilgili görüşleri, hem ön testten son teste; hem de son testten takip testine hiç bir kategoride anlamlı bir değişim bulunmamıştır.

Bilimsel Bilginin Öznelliği:

Bilimin doğasının önemli boyutlarından biri olan bilimin öznelliği konusunda, deney grubunda yetersiz görüşe sahip olan kişilerin ön testteki oranı, son testteki oranına göre istatistiksel olarak anlamlı şekilde farklıdır, $\chi^2 = 5.26$, $p = .019$. İki zaman dilimi karşılaştırıldığında, ön testte yetersiz görüşe sahip olanların yüzdesi son testtekinden çok daha yüksektir (% 40 ön testte, % 17 son testte). Deney grubundaki değişken görüşe sahip olanların oranında ise ön testten son teste anlamlı bir değişim ölçülmemiştir. Öte yandan bilgili görüşe sahip öğrencilerin yüzdesinde ise bilim tarihi eğitimi sonrasında anlamlı bir artış ölçülmüştür, $\chi^2 = 7.68$, $p = .004$. Karşılaştırma grubu öğrencilerinin bilimsel bilginin öznelliği konusunda ön test ve son testte ortaya koydukları görüşler incelendiğinde, istatistiksel olarak anlamlı bir artış ya da azalış gözlemlenmemiştir. Son testten takip testine, iki grupta da istatistiksel olarak anlam ifade eden bir değişiklik olmamış; öğrenciler takip testinde, son testte ortaya koydukları görüşlere oldukça paralel görüşler ortaya koymuşlardır.

Bilimsel Bilginin Delile Dayalı Doğası:

Bilimsel bilginin delile dayalı doğasıyla ilgili öğrencilerin ön testteki görüşleriyle son testteki görüşleri karşılaştırıldığında, bilim tarihi ile eğitim yapan gruptaki değişken görüşe sahip olanların oranı anlamlı oranda düşmüştür, $\chi^2 = 9.38$, $p = .002$. Uygulama öncesinde gruptaki kişilerin % 50 sinin görüşleri değişkenken, uygulama sonrasında bu oran % 17 ye gerilemiştir. Deney grubunda bilgili görüşe sahip olan öğrencilerin yüzdesi ön testten son teste % 25 den % 75 e yükselmiş ve bu yükseliş istatistiksel olarak da anlamlı olarak bulunmuştur, $\chi^2 = 16.53$, $p < .0005$. Bu iki ölçüm zamanında karşılaştırma grubundaki öğrencilerin görüşleri analiz edildiğinde, herhangi bir kategorideki öğrenci oranında istatistiksel olarak anlamlı bir fark bulunamamıştır. Her iki gruptaki öğrencilerin bu boyut açısından son testten takip testine ifade ettikleri görüşler açısından ne deney ne de karşılaştırma grubunda herhangi bir fark bulunamamıştır.

Bilimsel Bilginin Yaratıcılık ve Hayal Gücü İçermesi:

Bu boyut açısından, ön testten son teste her bir kategorideki öğrencilerin oranındaki gözlemlenen değişim karşılaştırıldığında, deney grubundaki bilgili görüşe sahip olan öğrencilerin yüzdesinde anlamlı bir artış olduğu gözlemlenmiştir, $\chi^2 = 4.5$, $p = .031$. Ön testte bilgili kategorisinde öğrenciler toplam öğrencilerin % 25 ini oluştururken bu oran son testte % 46 ya yükselmiştir. Karşılaştırma grubundaki öğrencilerin herhangi bir kategorideki oranında ön testten son teste anlamlı bir değişim olmamıştır. Her iki gruptaki öğrencilerin ise son testten takip testine görüşleri incelendiğinde, öğrencilerin son testte sahip oldukları görüşleri takip testinde de devam ettirdikleri gözlemlenmiş; iki grupta da herhangi bir artış ya da eksiliş bulunamamıştır.

Bilimsel Bilginin Çıkarımsal Yapısı:

Deney grubu öğrencilerinden, bilimsel bilgini çıkarımsal yapısı göz önüne alındığında, yetersiz görüş sergileyenlerin ön testten (% 75) son teste (% 38) istatistiksel olarak anlamlı şekilde azaldığı gözlemlenmiştir, $\chi^2 = 16.06$, $p < .0005$. Diğer taraftan aynı gruptaki değişken kategorisindeki öğrencilerin sayısı anlamlı derecede artmıştır, $\chi^2 = 4.50$, $p = .031$ (% 15'e göre % 35). Benzer şekilde, bilgili kategorisinde de ön testten (% 10) son teste (% 27) anlamlı bir artış gözlemlenmiştir, $\chi^2 = 4.90$, $p = .021$. Karşılaştırma grubunda ise, ön testten son teste hiç bir kategorideki kişilerin oranında istatistiksel olarak anlamlı değişim olmadığı bulunmuştur. Son testten takip testine öğrencilerin görüşleri grup bazında değerlendirildiğinde, ne deney ne de karşılaştırma grubunda anlamlı bir değişim olmadığı gözlemlenmiştir.

Özet olarak, bilim tarihi eğitimi dolaşım sistemi kavramlarını akılda tutma, fene karşı olumlu tutum geliştirme ve bu olumlu tutumu sürdürme, ayrıca bilimin doğası görüşlerini geliştirme ve bu gelişmiş görüşleri devam ettirme açılarından müfredat tabanlı eğitime göre daha etkili olduğu bulunmuştur. Bilimsel süreç becerilerini geliştirmede bilim tarihi eğitimi müfredat tabanlı eğitimden daha etkili olduğu bulunamamışsa da, bilim tarihi ile eğitim yapmanın da bu becerileri geliştirmede olumsuz bir yanına rastlanmamıştır.

Bu çalışmadan ortaya çıkan genel resme göre, bilim tarihi eğitimi fen okuryazarlığının temel bileşenlerini geliştirme yoluyla, öğrencilerin fen okuryazarlığını daha iyi bir yere taşımak için uygun bir ortam hazırlayabilmektedir.

Bu yüzden müfredat geliştiricilere Türkiye'de uygulanan fen ve teknoloji öğretim programına bilimin tarihini entegre etmesi tavsiye edilmekte; ayrıca fen bilgisi öğretmenlerine de sınıflarında bilim tarihinden daha aktif bir şekilde yararlanmaları önerilmektedir.

APPENDIX U

U. CURRICULUM VITAE

PERSONAL DETAILS

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EDUCATION

2008 – 2014 : PhD. Middle East Technical University, Elementary Education

2003-2008: B.S. Middle East Technical University, Elementary Science Education (GPA:3.34/4.00)

1999–2003: Eynesil High School (GPA: 5.00/5.00)

FOREIGN LANGUAGE

English

EXPERIENCE

03/2009-02/2010: Aksaray University, Research Assistant

02/2010-Present: Middle East Technical University, Research Assistant

TEACHING EXPERIENCE (TEACHING ASSISTANT)

Quantitative Data Analysis in Education

Analysis of Research in Science & Mathematics Education

Seminar in Elementary Science & Mathematics Education

Laboratory Applications in Science Teaching I-II

Methods of Teaching Science

School Experience

Practice Teaching in Elementary Education

RESEARCH RELATED ACTIVITIES

07/2012-08/2013: Visiting Scholar. University of Missouri, Department of Learning, Teaching, and Curriculum

PROJECT

January 2009- February 2009: Guide, Little Teachers are Touching the Science. Funded by Scientific and Technological Research Council of Turkey (TUBİTAK)

RESEARCH INTEREST

History of Science, Scientific Literacy, Nature of Science

MEMBERSHIP

National Association of Research in Science Teaching (NARST)

European Science Education Research Association (ESERA)

American Educational Research Association (AERA)

NATIONAL AND INTERNATIONAL PUBLICATIONS/ PRESENTATIONS

Cansiz, M., & Türker, N. (2011). Scientific literacy investigation in science curricula: The case of Turkey. *Western Anatolia Journal of Educational Sciences, Special Issue*, 359-366.

Keleş Ö., Ertaş H., Uzun N.& **Cansiz**, M. (2010). The understanding levels of preservice teachers' of basic science concepts' measurement units and devices, their misconceptions and its causes. *Procedia Social and Behavioral Sciences, 9*, p. 390-394

Cansiz, M., Sungur, S., & Oztekin, C. (2014). The effectiveness of teaching circulatory system through history of science. Paper presented in *American Educational Research Association (AERA)*

Cansiz, M., & Cansiz, N. (2014). Students' talk during collaborative group discussion. Paper presented in *International Conference on Education in Mathematics, Science & Technology*.

Cansiz, N., & **Cansiz, M**. (2014). Argumentation in peer-guided versus teacher-guided group discussions. Paper presented in *International Conference on Education in Mathematics, Science & Technology*.

Cansiz, N. & **Cansiz, M.** (2013). Exploring pre-service science teachers' orientations toward teaching science and science classroom practices: The role of early experiences. Paper presented in *10th biannual Conference of the European Science Education Research Association (ESERA).*

Cansiz, M., Sungur, S., & Oztekin, C. (2013). The role of history of science instruction on promoting favorable attitude toward science. Paper presented in *10th biannual Conference of the European Science Education Research Association (ESERA)*

Cansiz, M. & Türker, N. (2011). Scientific literacy investigation in science curricula: The case of Turkey. Paper presented in *World Conference on New Trends in Science Education.*

Cansiz, M. & Türker, N. (2011). Preservice teachers' sentiments, attitudes, concerns and self-efficacy about inclusive education (SACIE): Validation of SACIE scale. Paper presented in *National Association for Research in Science Teaching (NARST).*

Keleş Ö., Ertaş H., Uzun N.& **Cansiz, M.** (2010). The understanding levels of preservice teachers' of basic science concepts' measurement units and devices, their misconceptions and its causes. Paper presented in *World Conference on Learning, Teaching and Educational Leadership.*

AWARDS

2014: International Travel Award, American Educational Research Association

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü [ ]

Sosyal Bilimler Enstitüsü [x]

Uygulamalı Matematik Enstitüsü [ ]

Enformatik Enstitüsü [ ]

Deniz Bilimleri Enstitüsü [ ]

YAZARIN

Soyadı : Cansız
Adı : Mustafa
Bölümü : İlköğretim

TEZİN ADI : The Effect of History of Science Instruction on Elementary Students' Scientific Literacy

TEZİN TÜRÜ : Yüksek Lisans [ ] Doktora [x]

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. [ ]
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. [ ]
3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. [x]

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: