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Original Article

# Improving Middle School Students' Understanding about Scientific Inquiry through Creative Problem-Solving Modules enriched with the History of Science *

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## Abstract

Research showed that middle school students' understandings of scientific inquiry in Türkiye are inadequate in spite of the science curriculum reforms that have been conducted in recent years. And thus, contemporary science curricula should be organized as learning environments where students can find creative solutions to real-life problems using inquiry, collaboration, and reflection and can experience the process of creating scientific knowledge. In line with this, in this study, it was aimed to improve the understanding about scientific inquiry of middle school students through learning environments namely *Creative Problem-Solving Modules Enriched with History of Science*, and to compare their effectiveness with the current science curriculum.

The participants of the study were students in the 5th, 6th, and 7th grades, who were grouped as intervention (N=141) and control (N=77). Since it is a quasi-experimental study, classroom interventions namely *Creative Problem-Solving Modules Enriched with History of Science* were implemented in the intervention classrooms for one academic year, whereas in the control group classes, the Ministry of National Education Science (MoNE) curriculum practices, which has the vision of scientific literacy and is based on the inquiry-based teaching approaches, were applied. The data collection tool of the study was Views About Scientific Inquiry (VASI) Questionnaire developed by Lederman et al. (2014) which consists of open-ended questions. VASI was administrated as a pre-test and post-test to both groups, and additionally focus group interviews were conducted with VASI questions.

The results showed that the changes in the understanding of the aspects of SI-2 (*There is no single set or sequence of steps followed in all investigations*) and SI-8 (*Explanations are developed from a combination of collected data and what is already known*) were found statistically significant in favor of intervention groups. Moreover, although the lowest percentage of naïve students were found in the intervention

## Keywords

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groups prior to interventions, it was found that the current curriculum practices were not found as effective as the *Creative Problem-Solving Modules Enriched with History of Science* in improving these understandings of middle school students. In line with this, the *Creative Problem-Solving Modules Enriched with History of Science* helped students in the intervention groups to be at the informed level on all aspects of SI except SI-1 (*Scientific investigations all begin with a question but do not necessarily test a hypothesis*) and SI-2 (*There is no single set or sequence of steps followed in all investigations*). However, no students from the control groups were found at the informed level in 5 of 8 aspects of SI (SI-1, SI-2, SI-5, SI-7, and SI-8). While the effect of the *Creative Problem-Solving Modules Enriched with History of Science* interventions on the development of scientific inquiry understandings varies by grade level; it was also found that current inquiry-based science curriculum practices had a limited effect regardless of the grade level. The results showed that in the intervention groups in which the modules were implemented, *7th and 5th grades* were the ones who improved their understanding the most. In line with the study results, implications were discussed and recommendations for policymakers are provided.

## Introduction

Many countries aspire to cultivate individuals proficient in scientific literacy and equipped with 21st century competencies, through a proficient pedagogical approach achieved by the reforms of educational philosophies and the structure of their science curricula. The pursuit of fostering scientifically literate individuals is underpinned by two fundamental rationales of significance. The first is *the preparation of future scientists who have a direct impact on the development of the country*, and the second is *the preparation of informed decision-makers and well-equipped citizens.* Providing a learning experience in an environment similar to scientists in the science classes will enable students to understand scientific concepts, learn 'how the knowledge is created' science, understand the nature of science, and have the skills to conduct independent research and inquiry about the natural world and phenomena. This planned learning experience of collecting data, analyzing, making measurements, testing predictions, and using appropriate tools and equipment contributes to students' future career choices in science and their well-equipped upbringing (Bybee, 2006; Deboer, 2006). On the other hand, recognizing that not all students are destined for careers in the sciences the goal of fostering informed decision makers is to educate citizens who possess the capacity to inquire, engage in critical thinking, comprehend the functioning and societal impact of science, and adeptly access resources. The acquisition of these knowledge and skill sets, tailored to precise and targeted levels, is intricately linked to the advancement of scientific literacy (Deboer, 2006; Flick & Lederman, 2006; Lederman et al., 2014; National Research Council [NRC], 2000).

In line with the main goal of scientific literacy, reforms on the science curriculum of Türkiye have been made since 2004, and in line with these reforms, the educational philosophy process, strategy, and methods have started to be presented with more a research oriented and inquiry-based approach (MoNE, 2005, 2013; 2018). In these programs, "scientific inquiry" is emphasized as an important component of scientific literacy. In particular, with the goal of "*helping to understand how scientists create scientific knowledge, the processes of creating this knowledge and how it is used in new research*" (MoNE, 2018, p. 9), the effect of students' developing a correct understanding of the concept of scientific inquiry on the level of scientific literacy is indicated. With the inclusion of scientific inquiry understanding and skills in science curricula in Türkiye and other countries, studies aimed at determining and improving the current understanding of students and teachers about this concept have become more important. However, although it has been included in educational documents for many years, research on scientific inquiry is still limited (Bartels & Lederman, 2022; Doğan, Han-Tosunoglu, Özer, & Akkan, 2020).

Looking at the studies focusing on students' understanding of scientific inquiry Doğan et al.'s (2020) descriptive survey study, stands out in Türkiye with its large sample size of total N=599 middle school students in the 5th ,6th, and 7th grades. The results of this study revealed that the participants were found naïve in many aspects of the scientific inquiry. Another descriptive study was conducted by Lederman et al. (2019) with N=2634 7th graders in 18 different countries, including Türkiye with 268 7th grader students who were found mostly naïve in eight different aspects of scientific inquiry. In the current 12th grade survey study conducted by the same group (see Lederman et al., 2021), in which the scientific inquiry conceptions of 3917 12th grade students in 32 different countries, including Türkiye, were descriptively investigated, it was revealed that the 12th grade scientific inquiry conceptions of 119 12th grade students in Türkiye were at the naïve level in most of the eight different aspects, similar to the 7th grade results. Similar findings were found in Doğan, Han-Tosunoğlu, Arslan, Çakır, and İrez (2023)'s study in which N=3067 Turkish 9th grade students' understanding of scientific inquiry was examined and found mostly inadequate. Moreover, Senler's (2015) study, in which 251 middle school students from Türkiye and 238 middle school students from the United States (6th, 7th, and 8th grades) comparatively examined four dimensions of scientific inquiry conceptions. Senler (2015) stated that secondary school students in Türkiye were successful only in the aspect of scientific inquiry that "*there is no single scientific method followed in all research*" and had inadequate views in other aspects.

As frequently emphasized in many reform documents (Lederman et al., 2019), ensuring scientific literacy in a qualified way is directly related to students' having a conscious understanding of scientific inquiry skills and processes. These results in the related literature suggest that the science curriculum reforms in Türkiye are insufficient to improve the understandings of scientific inquiry of middle school students. In this context, it is necessary to support innovative practices that offer experiences to develop scientific inquiry understanding. When the relevant literature is examined, it was seen that the studies on the development of understanding on scientific inquiry generally consist of short-term experimental or quasi-experimental studies for teachers or preservice teachers, and there are a limited number of long-term experimental and quasi-experimental studies on the development of these views, especially in the context of students (Bolu, 2017; Doğan, 2017; Doğan et al., 2020; Erdaş-Kartal & Mesci, 2022; Mesci, Çavuş-Güngören, & Yesildag-Hasancebi, 2019; Özer & Doğan, 2022; Özer ve Sarıbaş, 2023). As it is known, the development of scientific inquiry understandings starts from the first years of the formal education, and the 5th, 6th, 7th, and 8th grade levels are considered to be the most critical levels where the knowledge about scientific literacy and competencies are developed (Bartels & Lederman, 2022; Doğan et al., 2020; Lederman et al., 2019, 2021; MoNE, 2015). In this context in line with nurturing scientifically literate individuals, this quasi-experimental study aimed to develop the scientific inquiry understandings of middle school students through long-term and innovative *Creative Problem-Solving Modules Enriched with the History of Science* and to compare their effectiveness with the current science curriculum. In line with this purpose, the research questions of the study are as follows:

> Research Question 1: Is there a difference between 5th, 6th, and 7th grade middle school students' understandings of scientific inquiry, who were taught with *Creative Problem-Solving Modules Enriched with the History of Science* and who were taught with current science curriculum?
>
> Research Question 2: Is there a difference between 5th, 6th, and 7th grade middle school students' understandings of scientific inquiry, who were taught with *Creative Problem-Solving Modules Enriched with the History of Science* and who were taught with current science curriculum, by grade level?

***Theoretical Framework***

***The Concept of Scientific Inquiry and Views on Scientific Inquiry***

In the current framework, the concept of scientific inquiry is defined as various processes carried out during the creation of knowledge in science (Flick & Lederman, 2006). According to Deboer (2006), the term scientific inquiry covers the entire research process used by scientists to answer questions about the phenomena of the natural world. Within the scope of these definitions, scientific inquiry means not only the doing of science but also the knowledge and understanding of the scientists about the process of creating scientific knowledge. Therefore, in this framework, the scientific inquiry concept consists of the ability to perform the scientific process and the knowledge and understanding of this process (Flick & Lederman, 2006).

As a pedagogical teaching approach, scientific inquiry emerged from the assumption that students can best learn science by doing. The historical foundations of the concept of scientific inquiry-based teaching can be traced back to the 1800s when different researchers such as Thomas Huxley (1825-1895), who was a biologist, and Herbert Spencer (1820-1903), who was also a biologist and a social scientist, and an educator Johann Friedrich Herbart (1776-1841) advocated the idea that science can best be learned by performing various activities in a laboratory environment and that scientists can be trained in this process. According to Deboer (2006), Huxley, Spencer, and Herbart emphasized that the capacity and skills of students to conduct independent research necessary to explain the events in nature in order to become scientists could be provided by including laboratory activities at every stage of formal education. In the early 1900s, the effectiveness of laboratory activities began to be discussed again. The social and industrial changes in this century led to the emergence of a paradigm in which students were provided with the knowledge and skills needed to solve the problems they would encounter in daily and social life and become informed individuals. Based on John Dewey's approach that the learning environment should be designed by combining learning-by-doing activities with reasoning processes, the concept of scientific inquiry was reinterpreted as a whole of both intellectual and cognitive, and psychomotor skills (Deboer, 2006). While ensuring personal development was the main goal of science education in the early 1900s, in the 1950s, inquiry-based teaching aimed to raise a society consisting of scientists and individuals with positive attitudes towards science. This new paradigm determined that an inquiry-based approach is not an activity that can only be conducted in the laboratory environment and now there is a consensus that scientific investigations can be conducted in different contexts, such as at libraries and/or field research. And in these learning environments should be designed as the students are offered problem-solving activities and practices similar to scientists (Deboer, 2006). With this consensus, it has started to be aimed that students understand the scientific process and the structure of scientific knowledge and become informed decision-makers through these learning environments experiences. In this context, in the National Science Education Standards (NSES-National Science Education Standards) science education reform document (NRC, 1996) published in the United States in 1996, the concept of scientific inquiry was broadly defined as follows (NRC, 1996, p.23):

> *"Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world."*

In this definition, inquiry-based learning can be expressed as a metaphorical reflection or model of the scientific inquiry process for students (Deboer, 2006). These learning environments can be described as environments in which students take an active role in the process, are responsible for their learning process by using their cognitive resources, carry out research-inquiry processes similar to those carried out by scientists with tasks to be determined in the classroom environment, and eventually develop accurate understandings about scientific inquiry (Flick & Lederman, 2006). This approach focuses on students' questioning, inquiry, and problem-solving. Just as the scientist carries out his/her research in the laboratory, field, library, and through discussions with colleagues, students carry out similar activities in an inquiry-based classroom environment (Deboer, 2006). In this context, in the National Science Education Standards (NSES) reform document (NRC, 1996), the understanding of scientific inquiry and the abilities necessary to make a scientific inquiry is defined separately for each grade level (K-4, 5-8, 9-12th grade) (Bybee, 2006; NRC, 1996). Subsequently, the concepts in the National Science Education Standards reform document were presented in a new framework as standards for K-12 level science teaching with a more updated perspective based on the American Association for the Advancement of Science (AAAS, 1993) and NRC (1996) reform documents in the name of Next Generation Science Standards (NGSS) (NRC, 2012) published by the same organization in 2012. In the document, the concept of scientific inquiry, which was central in the previous documents, is addressed as an important part of 'scientific and engineering practices,' which is a broader term and consists of 8 aspects. When the content of scientific and engineering practices is analyzed holistically, it is seen that it includes both science process skills and inquiry processes with activities such as designing/performing experiments, collecting data, analyzing, obtaining evidence, interpreting, social communication, model development, mathematical operations and developing explanations (Doğan & Özer, 2018). When scientific and engineering practices are combined with 21st century-based digital programs and activities integrated into hands-on, inquiry-based, hands-on, and laboratory activities, it is aimed to provide students with the knowledge and skills required by the century (Doğan & Özer, 2018).

In the domain of conceptions related to scientific inquiry, competencies encompassing scientific practices, scientific and engineering practices (as outlined by AAAS, 1993; NRC, 1996, 2000, 2012; National Academy of Sciences, 2002), and methodologies underscored by researchers in their investigations (Dunbar, 2001; Knorr-Cetina, 1999; Latour & Woolgar, 1979, as cited in Lederman et al., 2014) were examined by Lederman et al. (2014). They synthesized these elements from the literature to forge a conceptual framework, thereby shaping an assessment tool for scientific inquiry. This framework blends eight distinctive facets concerning conceptions of scientific inquiry, aligning harmoniously with the educational landscape spanning from early childhood to tertiary levels (Doğan et al., 2020; Lederman et al., 2014). In addition, it was aimed to develop a measurement tool that determines the scientific inquiry conceptions of students at different levels, to identify scientific inquiry conceptions, and to determine practices and policies for the development of scientific inquiry conceptions. These eight aspects and their explanations are presented in detail below (Lederman et al., 2014; Özer & Sarıbaş, 2023)

*1. Scientific investigations all begin with a question but do not necessarily test a hypothesis (SI 1)*

Scientific research involves asking and answering questions and comparing the answers with existing knowledge (NRC, 2000). Realizing a scientific inquiry requires asking a question about the natural world. On the other hand, scientific investigations do not always need to start with a hypothesis and test this hypothesis, as claimed in the classical scientific method steps (Lederman et al., 2014).

*2. There is no single set or sequence of steps followed in all investigations (SI 2)*

One of the important misconceptions about science in textbooks is that scientists use only one scientific method to produce scientific knowledge. However, it is known that scientists use different research methods depending on the questions they are trying to answer. For students to experience the scientific inquiry process effectively, they must understand that different methods are used to produce scientific knowledge.

*3. Inquiry procedures are guided by the questions asked- (SI 3)*

Scientists can investigate the answer to the same question by designing different inquiry processes. There is no single recommended step-by-step scientific method that can answer every question. For example, it would be difficult for paleontologists to find answers to their questions with experimental research methods (manipulating variables), so they must design their inquiry process differently. This example is important for understanding how a scientific question guides the process.

*4. All scientists performing the same procedures may not get the same results- SI 4*
Another aspect that students need to understand about the process of scientific inquiry is that scientific data can be interpreted in different ways. The main reason for this different interpretation is the theoretical background of scientists, what they decide as evidence, and how they deal with outliers in the data. These differences can lead to different conclusions by scientists examining the same data (Lederman et al., 2014).

*5. Inquiry procedures can influence the results- SI 5*
The inquiry process chosen in scientific research directly affects the scientific explanation to be produced at the end. The definition of variables, data collection methods, and how the variables will be measured and analyzed affect the conclusion of the researcher (Lederman et al., 2014).

*6. Research conclusions must be consistent with the data collected- SI 6*
The potency of scientific knowledge derives from its foundation upon empirical data and substantiating scientific evidence. The validity of the claim put forward in the scientific research process is supported by the research method chosen following the research question.

*7. Scientific data are not the same as evidence – SI 7*
Data is the name given to all the observations made in the scientific research process and can be in different structures (numbers, pictures, voice recordings, samples). Evidence is a product of the data analysis process. It is directly related to the research question and explanations (Lederman et al., 2014).

*8. Explanations are developed from a combination of collected data and what is already known.*
Scientific explanations should be supported by the results of previous studies and existing scientific knowledge, although they are generated from scientific evidence obtained as a result of the research. Scientists should be able to recognize when and how research results differ from existing scientific knowledge and how to interpret the data.

***Learning Approaches Supporting the Development of Understandings of Scientific Inquiry: Problem-Based Learning and History of Science***

One of the main objectives of science teaching is to provide students with necessary scientific thinking skills. For this purpose, the science course should be designed to include activities based on problem-solving and research inquiry in which students will actively take part in the center of the learning process, where they will experience a process similar to the process that scientists go through while doing science. Within these activities, students should be involved in different processes such as asking questions, defining the problem, generating hypotheses, making observations, collecting, and analyzing data, developing explanations, drawing conclusions, thinking critically, and evaluating the research investigations of their peers. These activities and the problem-solving process not only help students develop domain knowledge and scientific process skills about the topic under study but also help them understand the nature and structure of scientific knowledge (Chin & Chia, 2006; Chinn & Malhotra, 2002). According to Kolodner et al. (2003), inquiry-based learning and problem-based learning (PBL) are classified as pedagogical approaches that support the development of students' understanding of scientific inquiry due to their features such as designing and conducting research and inquiry, asking questions, collecting data, interpreting data, and requiring the transfer and use of learned knowledge on different problem situations. For many researchers, the main feature of these approaches is that the focus questions direct students to investigate "*what is happening?*" related to the open-ended problem or question, encourage them to use their prior knowledge, provide them with new knowledge as a result of their research, and involve the analysis and synthesis of what they have learned (Boyce, VanTassel-Baska, Burruss, Sher, & Johnson, 1997; Etherington, 2011; Feletti, 1993). Within this framework, it has been documented those methodologies like "problem-based learning (PBL)" and the incorporation of historical perspectives in science education, which have gained significant prominence, particularly since the 1980s, engender a demand for proficiencies including critical thinking, dynamic engagement, collaborative teamwork, and deliberative decision-making. These pedagogical approaches prompt students to recalibrate their perspectives by assessing diverse viewpoints and ruminating upon issues encompassing the delineation of real-world challenges, socio-scientific quandaries framed within a matrix of arguments, formulation of solution methodologies, data aggregation, as well as scrutiny and interpretation. Evidently, these methodologies hold potential efficacy in nurturing the advancement of scientific literacy (Matthews, 1994; Rotherham & Willingham, 2010, as cited in Hodges & Perthmer, 2015; Duch, Allen & White, 1999, as cited in Hodges & Perthmer, 2015). In the next section, the characteristics of these approaches are discussed.

***Problem-Based Learning and History of Science Approaches***

Dr. Howard Barrows, who worked at a medical school in Canada in the 1970s, observed that medical students had difficulty in applying the problem-solving and problem-related reasoning skills they had previously learned to different problem situations, that they could not reach a solution as a result of their inability to apply the knowledge they learned to daily life problems, and that they forgot these strategies in a short time (Barrows, 1996; Hung, 2016). Therefore, he needed a context-based method that included learning goals and strategies. Later on, he called this method problem-based learning (PBL). The approach, initially employed in basic medical sciences during the 1970s, has found its way into nearly all fields and levels ranging from primary and secondary education to high school and university since the 1980s driven by a growing body of research on its effectiveness. (Özer, 2021; Özer & Doğan, 2022; Savery, 2015). The problem-based learning approach is a student-centered method that aims to develop problem-solving skills and provide new learning by exposing the learner to well-structured or open-ended, relevant, daily life problem situations; to use the theoretical knowledge he/she has and to learn new concepts by accessing new information he/she needs in solving the problem in this process (Barrows, 1986, 1996, 2002; Hung, 2016; Özer & Doğan, 2022; Savery, 2015). The main aim of the approach is to develop the ability to use and apply knowledge, problem-solving, and self-learning skills as a result of a process in which students take an active role and work collaboratively (Barrows, 1996; Hmelo & Ferrari, 1997; Jonassen & Hung, 2008). In the problem-based learning approach, learners are in the role of questioning, researching, actively accessing, and constructing knowledge through a series of analytical and explanatory questions in learning with the question, "*What should I know*?". On the other hand, teachers are in the role of a guide who leads students to ask the right questions, shape the questions hierarchically, monitor the quality of group work activities on the problem, process skills, connection with content and individual development, and focus on content knowledge.

Based on the related literature, the history of science approach in science teaching is critical for developing scientific literacy. According to Matthews (1994), the history of science supports students' learning of scientific concepts and processes, helps them understand that doing science is an activity with ethical, cultural, and political interactions, and thus improves their understanding of scientific concepts and critical thinking skills. In addition, since the history of science approach includes the historical steps in the production of scientific knowledge and the development of science, the life stories of scientists, and the difficulties they faced throughout their lives, help students to understand and empathize with the process of scientific knowledge production and the research of scientists and makes them more motivated to learn science (Özer, 2021). According to Yıldız (2013), there are several different methods for teaching the history of science. These encompass *guided inquiry*, involving research and inquiry activities centered around historical elements of science; *the emulation of historical equipment*, delving into selected processes, products, and functions derived from the annals of scientific history; *creative writing*, wherein students harness their imagination and creativity rooted in historical events; and *the enactment of drama through role-playing*, reviving individuals, and events from the past. Matthews (1994) proposes that these techniques should be tailored for distinct utilization at each grade level, in conjunction with inquiry-based activities, to foster the cultivation of robust scientific literacy.

## Method

In this study, a non-equivalent control group design, one of the quasi-experimental designs, was used. The main difference between the non-equivalent control group design from the randomized pretest-posttest control group design in real experimental designs is that in cases where individuals cannot be randomly assigned to groups and classes, the process of determining the experimental-control groups is carried out randomly (Gay, Mills, & Airesian, 2012). In this study, there were experimental and control groups. The study participants were selected from public schools with the same demographic structure, as described in detail in the next section. During the transition from primary school to secondary school, the school administration randomly assigned the students to the classes. Experimental and control group students had the same educational background, grade level, and science teachers.

In the study, interventions called *Creative Problem-Solving Modules Enriched with History of Science* were carried out in the intervention group classes for one academic year. In the control group classes, the Ministry of National Education Science curriculum, which also has a vision of scientific literacy and is based on the research-inquiry-based teaching method, was implemented (MoNE, 2013, 2018).

### *Study Group*

The study was conducted with the participants of two public schools affiliated with the Ministry of National Education in the central district of a province in Türkiye. Therefore, the research participants were 5$^{th}$, 6$^{th}$, and 7$^{th}$ grade students studying in two secondary schools in the central district of the province. The study was conducted following the written ethical permissions obtained from the Provincial Directorate of National Education, University Social Sciences and Human Ethics Research Board (Permission No: Official Meeting decision dated 07.02.2017 and numbered 2017/02 Protocol No: 2017/41), School Principals, mentor teachers, pre-service teachers, and parents. The distribution of the students in the study group according to gender and grade level is shown in Table 1 and Table 2. As seen in Table 1 and Table 2, 53.2% (N=116 students) of the study group were female, and 46.8% (N=102 students) were male.

**Table 1.** Gender Distribution of Study Group Students

| Gender | Frequency (N) | Percentage (%) |
|---|---|---|
| Girl | 116 | 53.2 |
| Boy | 102 | 46.8 |
| **Total** | **218** | **100.0** |

The study groups comprised eight classes from 3 different grade levels (5$^{th}$, 6$^{th}$, and 7$^{th}$ grade). At least one intervention and control group class were selected from each grade level. The distribution of anonymously named class sections is shown in Table 2. The study included all the classes for which volunteer teachers were responsible. Therefore, there were two intervention classes (5-B, 5-E; 7-A, 7-D) and one control group (5-A, 7-C) class at the 5$^{th}$ and 7$^{th}$ grade levels. At the 6$^{th}$ grade level, there was one intervention (6-B) and one control (6-E) group class. As seen in Table 2, the participants of the study consisted of "3" 5$^{th}$ grade, "2" 6$^{th}$ grade, and "3" 7$^{th}$ grade students. The volunteer teachers' professional experience, educational status, and classroom information are also presented in Table 2. All necessary precautions were taken by the researchers to ensure that the teacher variable did not affect the results, and two teachers with the same educational background (graduated from the same universities) and similar professional experience conducted the study. In addition, the same teacher was required to teach both intervention and control classes. In order to obtain detailed and diverse data sources on the effects of the interventions, it was randomly selected that 2 of the classes with three classes would be the intervention group, and one would be the control group, and 1 of the classes with two classes would be the intervention group, and one would be the control group.

**Table 2**. Grade Level-Group Distribution of Study Group Students and Demographics of Teachers

| Grade Level | Group | Class-Branch | Number of Students | Total | Percentage (%) | Teacher's Name / Gender | Degree / Experience Year |
|---|---|---|---|---|---|---|---|
| **5th** | Intervention | 5-B | 25 | 84 | 38.5 | Teacher A / | B.A., M.A. / |
| | | 5-E | 30 | | | Female | 9 years |
| | Control | 5-A | 29 | | | | |
| **6th** | Intervention | 6-B | 32 | 59 | 27.1 | Teacher B / | B.A., M.A. / |
| | Kontrol Grubu | 6-E | 27 | | | Male | 10 years |
| **7th** | Intervention | 7-A | 26 | 75 | 34.4 | | |
| | | 7-D | 28 | | | | |
| | Control | 7-C | 21 | | | | |
| **Total** | | **8 classes** | | **218** | **100** | | |

***Intervention Process: Creative Problem-Solving Modules Enriched with History of Science***

Within the scope of the study, *Creative Problem-Solving Modules Enriched with the History of Science*, were developed according to the problem-based learning approach and compatible with the science curriculum objectives and were implemented for one year for the intervention group of students. The modules were developed, tested, and implemented over a period of approximately two years by the authors within the scope of a research project (Özer, 2021; Özer & Doğan, 2022). The *Creative Problem-Solving Modules Enriched with the History of Science* aimed to develop students' 21st century skills, such as problem-solving and creativity, while supporting the development of their views on scientific inquiry and becoming scientifically literate individuals. In this context, in addition to the problem-based learning approach, scientific and engineering practices (NRC, 2012) and the history of science approaches were also utilized in the design process of the modules (Özer & Doğan, 2022). The aim of the history of science sections in the modules was to enable students to establish a relationship between the topics covered in the problem scenarios and the history of science and the related works of scientists and to emphasize the problem-solving and creative solution development processes and practices frequently seen in the history of science. In these sections, different story examples from the history of science, selected from the relevant literature in line with the module content, were presented to students through various questioning, timeline analysis, story writing, inference, constructing explanation, and role-playing techniques (Özer, 2021; Özer & Doğan, 2022).

Module implementations were carried out in groups according to the schedule determined for the intervention group students in the first and second semesters of an academic year. During the implementation process that lasted for one academic year, four modules were implemented by the science teacher for each grade level in the intervention group and with the mentorship of the authors. In the classes in the control group, the science courses were taught by the responsible science teachers as stipulated by the current curriculum. Before the module implementations, informative meetings were held with the teachers, detailed information about the PBL approach and the implementation process was presented to them, and training was organized. In addition, "Teacher Copies" of the modules, which were specially prepared for the teachers and included the instructions for implementation, were shared with the teachers electronically in advance to each implementation within the schedule.

The indicator table shows grade level, the unit, objective, information and details about the activities, problem scenarios, duration, history of science, and targeted scientific inquiry aspect (Lederman et al., 2014) of the modules implemented within the scope of the study in comparison with the science curriculum (MoNE, 2013, 2018) is presented as Appendix (please see Appendix 1).

***Data Collection Tools***

*1. Views about Scientific Inquiry Questionnaire – VASI*

The data collection tool of the study was the open-ended Views About Scientific Inquiry Questionnaire (VASI) developed by Lederman et al. (2014). The questionnaire was developed in order to identify views about scientific inquiry based on eight (8) aspects in English (Doğan et al., 2020). The current version of the VASI is a more comprehensive and expanded version of the Views of Scientific Inquiry (VOSI) (Schwartz, Lederman, & Lederman, 2008), which was first developed in 2008 and consists of 5 open-ended questions and includes 5 of the aspects of scientific inquiry (Lederman et al., 2014). The questionnaire was tested by Lederman et al. (2014) in different states of the United States of America, in different schools, at different levels (K-12), in physics, chemistry, biology, and science courses, on preservice teachers and teachers, and its validity and reliability were analyzed. Afterward, it was applied in different countries worldwide at different levels. VASI consists of seven main open-ended questions measuring eight scientific inquiry aspects. There are sub-questions with different options under 3 of the seven questions (e.g., 1a, 1b, 1c, 3a, 3b, 7a, 7b). The questions were structured in a way to measure students' levels of understanding of scientific inquiry aspects holistically. Accordingly, the aspects of scientific inquiry and the corresponding questions and sub-questions in the questionnaire are presented below.

**Table 3.** Aspects of SI and corresponding items of VASI (Lederman et al., 2014, p.76)

| Aspects of Scientific Inquiry | VASI Item # |
|---|---|
| 1. Scientific investigations all begin with a question and do not necessarily test a hypothesis | 1a, 1b, 2 |
| 2. There is no single set or sequence of steps followed in all investigations | 1b, 1c |
| 3. Inquiry procedures are guided by the question asked | 5 |
| 4. All scientists performing the same procedures may not get the same results | 3a |
| 5. Inquiry procedures can influence results | 3b |
| 6. Research conclusions must be consistent with the data collected | 6 |
| 7. Scientific data are not the same as scientific evidence | 4 |
| 8. Explanations are developed from a combination of collected data and what is already known | 7 |

The Turkish adaptation study of the questionnaire was conducted by Han-Tosunoğlu, Doğan, Yalaki, Çakır, and İrez (2017). The necessary permissions to administer the questionnaires were obtained from the authors. The average administration time of the questionnaire varied between 30-40 minutes for middle school students. The VASI was administered twice to the same students in all groups (intervention and control) and at all grade levels: a pre-test in September before the interventions started and a post-test in June after the interventions' completion. The students were asked to answer the questionnaire as clearly and comprehensibly as possible; it was emphasized that they could also state their responses by drawing, using different colored pens/pencils or visuals if necessary, and that there were no right or wrong answers.

*2. Semi-Structured Focus Group Interviews*

Semi-structured interviews consisting of survey questions were conducted to understand student responses to the VASI questionnaire better and allow students to elaborate on their responses. Semi-structured interviews were conducted with groups of 6-7 students. According to Lederman et al. (2014), conducting interviews with an average of 20% of the surveyed group is recommended. However, semi-structured focus group interviews were conducted with N=48 students (22% of the total student group) after the pre-test applications and with all students (N=218 students / 100%) after the post-test applications. The interviews were completed in 25-30 minutes on average. All interviews were recorded with recorder devices, and the responses were transcribed and used to support the written responses given by the students in the data analysis.

***Data Analysis***

*1. Views about Scientific Inquiry Questionnaire – VASI*

The responses to the VASI were analyzed holistically with the content analysis technique, one of the qualitative data analysis methods. The content analysis technique is a scientific data analysis method that systematically examines texts containing various verbal and written expressions to create codes, groups, and themes (Weber, 1990). For the whole data to be analyzed with the content analysis method and the results to be drawn to be reliable and valid, they should be examined by different researchers simultaneously, and their consistency should be systematically monitored (Roberts, Priest, & Traynor, 2006).

The responses were analyzed in 3 categories with the help of rubrics developed by Lederman et al. (2014). These categories are *naïve*-1, *mixed* (transitional)-2, and *informed*-3. Expected general explanations about the scientific inquiry understandings related to these levels are presented below:

- ***Naïve-1:*** Participants provide baseless explanations for the relevant scientific inquiry component that contradict or are inconsistent with accepted views.
- ***Mixed (transitional)-2:*** Participants' explanations of the relevant scientific inquiry component were partially adequate but provided inconsistent explanations with the expected answer.
- ***Informed -3:*** Participants provide coherent, expected, elevated explanations of the relevant scientific inquiry component.

In addition, these explanations were graded separately for each aspect. The evaluation rubric Lederman et al. (2014) developed based on students' sample responses regarding these aspects was used. In addition to the rubrics developed by Lederman et al. (2014), it is stated that in studies using VASI, rubrics should be created from the data obtained from the surveyed groups and presented as sample responses. Therefore, the rubric for sample student responses selected from the VASI responses obtained in this study is presented in the appendix (see Appendix 2).

The analysis of the VASI questionnaire was conducted in three stages. These stages are explained in detail below respectively:

1. In the first stage, the authors coded ten student questionnaires randomly selected from the pre-tests with the help of the relevant rubrics and tried to determine the consistency in the coding process and the conformity with the aspects of scientific inquiry. The authors participated in coding training organized by VASI developers on coding this questionnaire. In addition, apart from this study, they had previously coded the same questionnaire in different studies (Doğan et al., 2020).
2. Ten randomly selected questionnaires were individually coded in the second stage, and then the results were compared. The coding results were entered into an MS Office Excel file for each scientific inquiry aspect. This stage of coding was proposed by Lederman et al. (2019), the team that developed the questionnaire in which the authors participated, as a method of finding inter-coder reliability for the questionnaire during the training on questionnaire evaluation at the NARST 2019 Congress. Within the scope of this research, the example used by the authors for a single aspect is presented below as a table (see Table 4). Accordingly, each coder entered the codes related to the aspects into the table, and the agreement was determined as 100% if the evaluation degree for the scientific inquiry aspects was the same and 0% if it was different. Then, the arithmetic averages of the agreement for each aspect were calculated, and at the end of the process, the arithmetic average of the inter-coder agreement rates of all aspects was taken. Accordingly, the inter-coder agreement for all aspects was calculated as 91.25%.

**Table 4.** Example of VASI Inter-rater Agreement Rate Calculation Chart

| | Rater 1 | Rater 2 | Agreement Rate |
|---|---|---|---|
| | SI-1 Category | SI-1 Category | (%) |
| **Student 1** | 1 | 1 | 100 |
| **Student 2** | 1 | 1 | 100 |
| **Student 3** | 1 | 1 | 100 |
| **Student 4** | 1 | 1 | 100 |
| **Student 5** | 1 | 1 | 100 |
| **Student 6** | 2 | 1 | 0 |
| **Student 7** | 1 | 1 | 100 |
| **Student 8** | 1 | 1 | 100 |
| **Student 9** | 1 | 1 | 100 |
| **Student 10** | 1 | 1 | 100 |
| Agreement rate for SI-1 aspect | | | **95%** |

3. In the last stage, since the agreement rate was above the limit (80%) set by the researchers who developed the questionnaire (Lederman et al., 2014), the first author conducted the evaluation of all other questionnaires.

The codes obtained from student responses were entered into the SPSS statistical data analysis program based on aspects. The data were analyzed using descriptive statistical methods as suggested by Lederman et al. (2014). However, inferential statistical methods (Wilcoxon Signed Rank Test and Mann-Whitney U Test) were also used to test the statistical significance of the effectiveness of the intervention practices on the intervention and control groups.

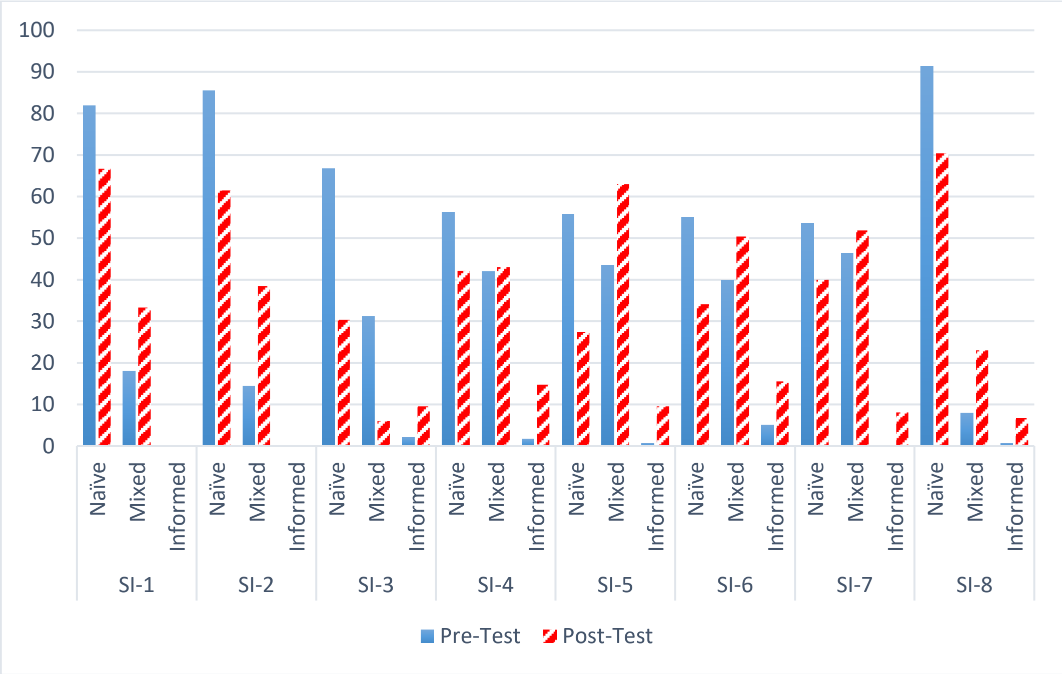
*2. Analysis of Semi-Structured Focus Group Interview*

As mentioned in Methodology section 3.2, semi-structured interviews with groups of 6-7 students were conducted and recorded to understand student responses better and allow students to elaborate on their responses. All interviews were transcribed. The interview transcriptions, together with the students' responses to the questionnaires, were used to evaluate the questionnaires.

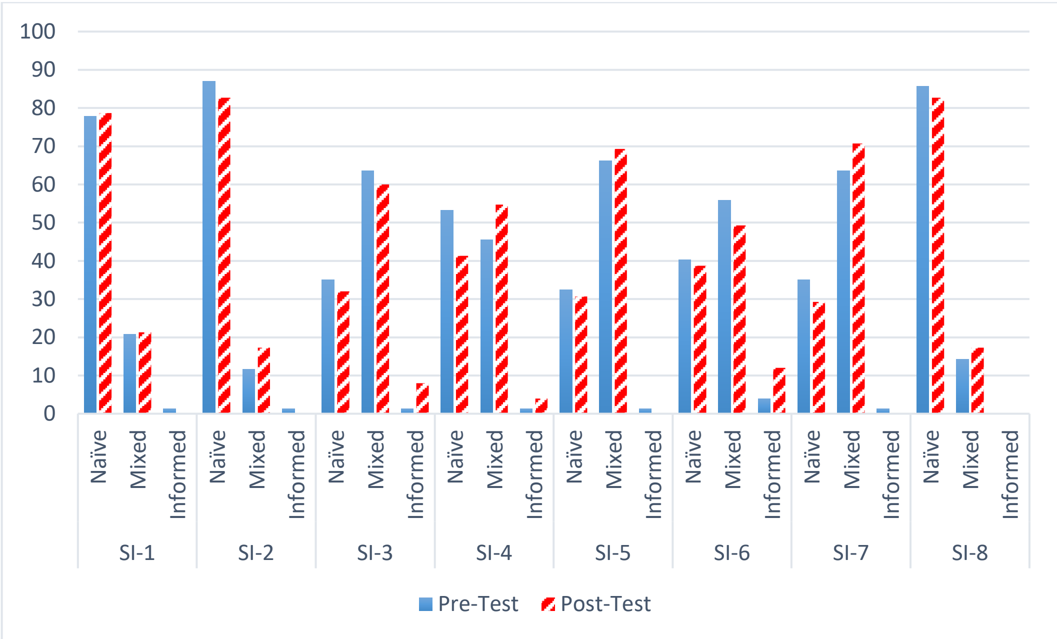
## Results

***Findings of the Research Question 1: Is there a difference between 5th, 6th, and 7th grade middle school students' understandings of scientific inquiry, who were taught with Creative Problem-Solving Modules Enriched with the History of Science and who were taught with current science curriculum?***

In this section, the changes in the intervention and control groups regardless of grade levels were examined holistically, and descriptive analyses of the understandings on scientific inquiry are presented in Table 5, Graph 1, and Graph 2. In addition to that non-parametric Mann-Whitney U tests were used to analyze whether there were differences between the groups (intervention-control) regarding the understandings on scientific inquiry aspects, and these findings are presented in Table 6. Mann-Whitney U test is a statistical test used to examine whether the difference between the mean scores of independent samples is significant in cases where data distribution is not normal (Can, 2014).




**Graph 1.** Changes in Intervention groups' Understanding of Scientific Inquiry




**Graph 2.** Changes in Control Groups' Understanding of Scientific Inquiry

**Table 5.** Descriptive Comparisons of the Changes in the Pre-Test and Post-Test Scientific Inquiry Understandings of the Intervention and Control Groups

| | | **Control Groups** | | | | **Intervention Groups** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Pre-Test** | | **Post-Test** | | **Pre-Test** | | **Post-Test** | |
| **Aspect of Scientific Inquiry** | **Category** | **Frequency (N)** | **Percentage (%)** | **Frequency (N)** | **Percentage (%)** | **Frequency (N)** | **Percentage (%)** | **Frequency (N)** | **Percentage (%)** |
| 1. Scientific investigations all begin with a question and do not necessarily test a hypothesis (SI 1) | Naïve | 60 | 77.9 | 59 | 78.7 | 113 | 81.9 | 90 | 66.7 |
| | Mixed | 16 | 20.8 | 16 | 21.3 | 25 | 18.1 | 45 | 33.3 |
| | Informed | 1 | 1.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 2. There is no single set or sequence of steps followed in all investigations (SI 2) | Naïve | 67 | 87.0 | 62 | 82.7 | 118 | 85.5 | 83 | 61.5 |
| | Mixed | 9 | 11.7 | 13 | 17.3 | 20 | 14.5 | 52 | 38.5 |
| | Informed | 1 | 1.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 3. Inquiry procedures are guided by the question asked (SI 3) | Naïve | 27 | 35.1 | 24 | 32 | 92 | 66.7 | 41 | 30.4 |
| | Mixed | 49 | 63.6 | 45 | 60 | 43 | 31.2 | 81 | 60 |
| | Informed | 1 | 1.3 | 6 | 8 | 3 | 2.1 | 13 | 9.6 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 4. All scientists performing the same procedures may not get the same results (SI 4) | Naïve | 41 | 53.2 | 31 | 41.3 | 78 | 56.3 | 57 | 42.2 |
| | Mixed | 35 | 45.5 | 41 | 54.7 | 58 | 42 | 58 | 43 |
| | Informed | 1 | 1.3 | 3 | 4 | 2 | 1.7 | 20 | 14.8 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 5. Inquiry procedures can influence results (SI 5) | Naïve | 25 | 32.5 | 23 | 30.7 | 77 | 55.8 | 37 | 27.4 |
| | Mixed | 51 | 66.2 | 52 | 69.3 | 60 | 43.5 | 85 | 63 |
| | Informed | 1 | 1.3 | 0 | 0 | 1 | .7 | 13 | 9.6 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 6. Research conclusions must be consistent with the data collected (SI 6) | Naïve | 31 | 40.3 | 29 | 38.7 | 76 | 55.1 | 46 | 34.1 |
| | Mixed | 43 | 55.8 | 37 | 49.3 | 55 | 39.9 | 68 | 50.4 |
| | Informed | 3 | 3.9 | 9 | 12 | 7 | 5.0 | 21 | 15,6 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7. Scientific data are not the same as scientific evidence (SI 7) | Naïve | 27 | 35.1 | 22 | 29.3 | 74 | 53.6 | 54 | 40 |
| | Mixed | 49 | 63.6 | 53 | 70.7 | 64 | 46.4 | 70 | 51.9 |
| | Informed | 1 | 1.3 | 0 | 0 | 0 | 0 | 11 | 8.1 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |
| 8. Explanations are developed from a combination of collected data and what is already known (SI 8) | Naïve | 66 | 85.7 | 62 | 82.7 | 126 | 91.3 | 95 | 70.4 |
| | Mixed | 11 | 14.3 | 13 | 17.3 | 11 | 8 | 31 | 23 |
| | Informed | 0 | 0 | 0 | 0 | 1 | .7 | 9 | 6.7 |
| | **Total** | **77** | **100** | **75** | **100** | **138** | **100** | **135** | **100** |

**Table 6.** Comparison of the Changes in the Pre-Test and Post-Test Scientific Inquiry Understanding of the Intervention and Control Groups with the Mann-Whitney U Test

| Aspect of Scientific Inquiry (Pre/Post) | Group | N | Mean Rank | Sum of Ranks | Mann-Whitney U | Z | P (Sig.) | Effect Size (r = Z / √N) |
|---|---|---|---|---|---|---|---|---|
| **Pre SI-1** | Intervention | 138 | 106.38 | 14681.00 | | | | |
| | Control | 77 | 110.90 | 8539.00 | 5090.000 | -.742 | .458 | |
| | *Total* | 215 | | | | | | |
| **Post SI-1** | Intervention | 135 | 110.00 | 14850.00 | | | | |
| | Control | 75 | 97.40 | 7305.00 | 4455.000 | -1.831 | .067 | 0.12 |
| | *Total* | 210 | | | | | | |
| **Pre SI-2** | Intervention | 138 | 108.51 | 14974.00 | | | | |
| | Control | 77 | 107.09 | 8246.00 | 5243.000 | -.267 | .790 | |
| | *Total* | 215 | | | | | | |
| **Post SI-2** | Intervention | 135 | 113.44 | 15315.00 | | | | |
| | Control | 75 | 91.20 | 6840.00 | 3990.000 | -3.174 | **.002** | 0.21 |
| | *Total* | 210 | | | | | | |
| **Pre SI-3** | Intervention | 138 | 96.21 | 13277.00 | | | | |
| | Control | 77 | 129.13 | 9943.00 | 3686.000 | -4.290 | .000 | |
| | *Total* | 215 | | | | | | |
| **Post SI-3** | Intervention | 135 | 106.48 | 14374.50 | | | | |
| | Control | 75 | 103.74 | 7780.50 | 4930.500 | -.360 | .719 | 0.02 |
| | *Total* | 210 | | | | | | |
| **Pre SI-4** | Intervention | 138 | 106.78 | 14736.00 | | | | |
| | Control | 77 | 110.18 | 8484.00 | 5145.000 | -.444 | .657 | |
| | *Total* | 215 | | | | | | |
| **Post SI-4** | Intervention | 135 | 107.56 | 14520.50 | | | | |
| | Control | 75 | 101.79 | 7634.50 | 4784.500 | -.727 | .467 | 0.05 |
| | *Total* | 210 | | | | | | |
| **Pre SI-5** | Intervention | 138 | 98.99 | 13660.00 | | | | |
| | Control | 77 | 124.16 | 9560.00 | 4069.000 | -3.272 | 001 | |
| | *Total* | 215 | | | | | | |
| **Post SI-5** | Intervention | 135 | 109.23 | 14745.50 | | | | |
| | Control | 75 | 98.79 | 7409.50 | 4559.500 | -1.426 | .154 | 0.09 |
| | *Total* | 210 | | | | | | |
| **Pre SI-6** | Intervention | 138 | 102.79 | 14185.00 | | | | |
| | Control | 77 | 117.34 | 9035.00 | 4594.000 | -1.859 | .063 | |
| | *Total* | 215 | | | | | | |
| **Post SI-6** | Intervention | 135 | 107.83 | 14557.50 | | | | |
| | Control | 75 | 101.30 | 7597.50 | 4747.500 | -.821 | .412 | 0.05 |
| | *Total* | 210 | | | | | | |
| **Pre SI-7** | Intervention | 138 | 100.62 | 13886.00 | | | | |
| | Control | 77 | 121.22 | 9334.00 | 4295.000 | -2.686 | .007 | |
| | *Total* | 215 | | | | | | |
| **Post SI-7** | Intervention | 135 | 103.66 | 13994.00 | | | | |
| | Control | 75 | 108.81 | 8161.00 | 4814.000 | -.679 | .497 | 0.04 |
| | *Total* | 210 | | | | | | |
| **Pre SI-8** | Intervention | 138 | 105.89 | 14612.50 | | | | |
| | Control | 77 | 111.79 | 8607.50 | 5021.500 | -1.245 | .213 | |
| | *Total* | 215 | | | | | | |
| **Post SI-8** | Intervention | 135 | 110.54 | 14923.50 | | | | |
| | Control | 75 | 96.42 | 7231.50 | 4381.500 | -2.132 | **.033** | 0.14 |
| | *Total* | 210 | | | | | | |

*1. Scientific research always starts with a question but does not necessarily test a hypothesis (SI-1)*

According to the pre-test results of all students in the intervention and control groups, a large proportion of them had a *naïve* level of understanding of the SI-1 aspect (intervention group: 81.9%; control group: 77.9%). This finding is quite similar to the descriptive test results conducted on middle school level in Türkiye. In this aspect, the vast majority of middle school students have *naïve* level understandings (Doğan et al., 2020; Lederman et al., 2019, 2021; Senler, 2015).

In the posttests, an increase was observed in the number of *naïve* students in the control groups (78.7%), whereas a decrease was observed in the number of naïve students in the intervention groups (66.7%). While a small increase was observed in the number of students at the *mixed* level in the control groups (21.3%), it was observed that the number of students at the *mixed* level increased significantly in the intervention groups (33.3%). This increase was also reflected in the interviews with the students regarding the difference in the expressions used. The statements of a student in the 5th grade intervention group regarding this aspect before and after the interventions are presented below as an example. As seen in the example of student #23, it was observed that many students within the intervention group exhibited an elevated degree of comprehension regarding the distinction between a scientific investigation (1a) and an experiment (1b), as well as recognized of the imperative role of questions within scientific investigations (2).

> ***[Intervention G. 5th Grade Student #23, Pre-Test, and Interview]:*** *"1a: I think it is scientific because at least he was curious and searched. 1b: It is an experiment. 2: I agree with the one who says no."* ***(naïve) [Intervention G. 5th Grade Student #23, Posttest, and Interview]:*** *"1a: It is scientific research. There was something they observed animals. Living things are also observed in science lessons. 1b: My teacher is researching. It is not an experiment. 2: Scientific research should start with a question* ***(mixed)***

Similar to the pre-test results, there were no students at the *informed* level in this aspect in the post-tests in both groups (0%). The posttest results of the Mann-Whitney U Test shown in Table 6 show no significant difference between the intervention and control groups in this aspect (U=4455.000, p=0.067, p>0.05).

*2. There is no uniform/step-by-step way to conduct scientific research (SI-2)*

According to the pre-test results of all students in the intervention and control groups, a large proportion had a *naïve* level of understanding of the SI-2 aspect (intervention group: 85.5%; control group: 87%). In the posttest applications, while there was no significant change in the number of *naïve* students in the control group (82.7%), there was a significant decrease in the number of *naive* students in the intervention group (61.5%). At the *mixed* level, increases were observed in both groups, but the increase in the intervention group was sharper (38.5% in the intervention group; 17.3% in the control group). A sample student quotation regarding the increase in the *mixed* level in the intervention group is presented below. As can be seen from the quotation, it is seen that the 5th grade student #24 developed a more comprehensive understanding of what characteristics a research question should have when deciding whether it is an experiment or not in the first part of the question (1b). In the second part of question (1c), it was observed that he developed his incomplete view that scientific research would follow a single method after the practices.

> ***[Intervention G. 5th Grade Student #24, Pre-Test, and Interview]:*** *"1b: No, it is not an experiment because experiments are done by doing. 1c: No, there cannot be different methods because we need to respect everyone's opinion."* ***(naïve)***

> ***[Intervention G. 5th Grade Student #24, Posttest, and Interview]:*** *"1b: No, it is not an experiment. Because he is not experimenting on anything or pouring or anything. He is only investigating the beak of a single bird or something. There are no features of an experiment here! 1c: There is more than one method. You know, my teacher, for example, people can do a job, they can do a job and then continue it, they can do it in every subject."* ***(mixed)***

In this aspect, similar to the results in the SI-1 aspect, there were no students at the *informed* level in both groups in the posttests (0%). However, the Mann-Whitney U Test post-test results shown in Table 6 show a significant difference between the intervention and control groups in the context of this aspect *in favor of the intervention* groups (U=3990.000, p=0.002, p<0.05).).

*3. Scientific research processes are shaped by the question asked (SI-3)*

In the SI-3 aspect, the majority of the students in the control group in the pretests were at the levels of *mixed* (63.6%), *naïve* (35.1%), and *informed* (1.3%), respectively. In the intervention groups, the opinions of the students regarding this aspect were *naïve* (66.7%), *mixed* (31.2%), and *informed* (2.2%), respectively. In the posttest results after the interventions, it was observed that the number of students at the *naïve* (32%) and *mixed* (60%) levels in the control groups decreased, while the number of students at the *informed* (level increased (8%).

In the intervention groups, the number of students at the *naïve* level decreased significantly (30.4%), while the number of students at the *mixed* (60%) and informed (9.6%) levels increased significantly. Two different student responses showing this development are presented below as examples. The example presented by the 5th grade student #18 during the pretest and the first interview shows that he could not correctly identify the characteristics of scientific inquiry and did not understand it correctly. However, it is seen that he developed a partially correct understanding of scientific research variables after the practice.

***[Intervention G. 5th Grade Student #18, Pre-Test, and Interview]:*** *"Group A. Because they both thought of the possibility of a flat tire."* ***(naïve)***

***[Intervention G. 5th Grade Student #18, Posttest, and Interview]:*** *"I think it is the second one. When they try a tire on different roads, they see which one can go flat. They look at which ones it can go flat and which ones it cannot."* ***(mixed)***

Another sample student response regarding the development in the intervention group is student #17 at the 6th grade level. It was observed that the student had a partially correct understanding of the characteristics of scientific research before the interventions, but after the interventions, he could correctly identify these parameters.

***[Intervention G. 6th Grade Student #17, Pre-Test, and Interview]:*** *"The research process followed by option B identifies three different paths."* ***(mixed)***

***[Intervention G. 6th Grade Student #17, Posttest, and Interview]:*** *"B is better. If my teacher uses a C brand tire with three tires, one asphalt, one sand, one gravel, they look at how each tire goes on the roads and whether it punctures or not."* ***(informed)***

The Mann-Whitney U Test post-test results in Table 6 reveal no significant difference between the intervention and control groups in this aspect (U=4930.500, p=0.719, p>0.05).

*4. All scientists applying the same processes may not reach the same conclusions (SI-4)*

According to the pre-test results in the SI-4 aspect, the percentages of students in the intervention and control groups were quite close to the percentages of students at *naïve*, *informed*, and *mixed* levels. In the post-test results, some differences were observed between the groups. Accordingly, the number of *naïve* students in the control group decreased (41.3%), while the number of *mixed* (54.7%) and *informed* (4%) students increased. Similar to the control group, the number of naïve students in the intervention group decreased (42.2%). There was a small increase in *mixed* students (43%) and a significant increase in *informed* students (14.8%). This increase in the informed level was the highest increase at this level among the other aspects. Below are sample student quotations showing the transition of the intervention group student at two different grade levels to the informed level. For example, when the quotation of student #10 in 5th grade is analyzed, it is seen that although the student had a partially correct understanding of the subject before the application, he could not express these features clearly. After the intervention, it is seen that he referred to the forms of scientific research and other features from a broader perspective.

***[Intervention G. 5th Grade Student #10, Pre-test, and Interview]:*** *"No, some may have a different opinion. They may have thought differently. Therefore, their experiments will be different."* **(*mixed*)**

***[Intervention G. 5th Grade Student #10, Posttest, and Interview]:*** *My teacher, for example, will research something, but the ways of research are the same, but when they add their ideas, those ideas, that way can change"* ***(informed)***

A similar example was seen in the 7th grade student #10 whose sample quotation is presented below. It is seen that the student had no idea about the subject before the interventions, but after the interventions, he could clearly express scientists' contribution to scientific research processes.

***[Intervention G. 7th Grade Student #10, Pre-test, and Interview]:*** "*I have no idea, I do not know."* ***(naïve)***

***[Intervention G. 7th Grade Student #10, Posttest, and Interview]:*** *"I think they cannot reach the same conclusion. Different scientists have different working methods, different views, they have received different education."* ***(informed)***

The Mann-Whitney U Test posttest results shown in Table 6 show no significant difference between the intervention and control groups in terms of this aspect (U=4784.500, p=0.467, p>0.05).

*5. Scientific research processes can have an impact on results (SI-5)*

The pre-test results of this aspect showed that the students in the intervention group had *naïve* (55.8%), *mixed* (43.5%), and *informed* (0.7%) levels of understanding, respectively. In the pre-test results, the majority of the students in the control group were found to be *mixed* (66.2%), then *naïve* (32.5%), and *informed* (1.3%). In the posttest results after the interventions, it was determined that the number of *naïve* students in both groups decreased (intervention group: 27.4%; control group: 30.7%) and the number of *mixed* students increased (intervention group: 63%; control group: 69.3%). In the posttests, while there were no students at the *informed* level in the control group, there was an increase in the number of students at the *informed* level in the intervention group (9.6%). Below is a quotation from a 7th grade student #9 who was at the *naïve* level before the interventions as an example of her development after the interventions. Similar to the previous aspect, it is seen that the student had no idea about the subject before the intervention, but after the interventions, he/she reached a level where he/she could clearly express the contribution of scientists to scientific research processes.

***[Intervention G. 7th Grade Student #9, Pre-test, and Interview]:*** *"I do not know."* **(*naïve*)**

***[Intervention G. 7th Grade Student #9, Posttest, and Interview]:*** *"I think they cannot reach the same conclusion. Scientists may have different working methods, different views, and different training. It will be different. Because when there is more time, there is more research time."* ***(informed)***

The Mann-Whitney U Test posttest results in Table 6 indicate no significant difference between the intervention and control groups in this aspect (U=4559.500, p=0.154, p>0.05).

*6. Research results should be consistent with the data obtained (SI-6)*

Within the context of the SI-6 aspect, a predominant proportion of students within the control group demonstrated varying degrees of understanding: *mixed* (55.8%), followed by *naïve* (40.3%), and finally, *informed* (3.9%). Conversely, in the intervention groups, student perspectives concerning this topic were characterized as follows: *naïve* (55.1%), *mixed* (39.9%), and *informed* (5.1%), respectively. Following the implementation, a decrease was noted in the count of students categorized as *naïve* in both groups (intervention group: 34.1%; control group: 38.7%). Conversely, it was observed that the count of students classified as mixed in the control group decreased (49.3%), while in the intervention group, this count witnessed an increase (50.4%). A rise in the count of *informed* students was evident in both groups (intervention group informed 15.6%; control group informed (12%). The outcomes of the Mann-Whitney U Test posttest, presented in Table 6, indicate that there exists no substantial distinction between the intervention and control groups concerning this theme (U=4747.500, p=0.412, p>0.05).

*7. Scientific evidence is not the same as scientific data (SI-7)*

In the SI-7 aspect, the pre-test results showed that the majority of the students in the control group were *mixed* (63.6%), *naïve* (35.1%), and *informed* (1.3%), respectively. On the other hand, the understanding of the students in the intervention groups regarding this theme were at the *naïve* (53.6%) and *mixed* (46.4%) levels, respectively. According to the pre-test results, there were no students at the *informed* level in the intervention group (0%). When the posttest results were analyzed after the application, although there was a decrease in the percentage of *naïve* students (29.3%) and an increase in the percentage of *mixed* students (70.7%) in the control group students, no student was found at the *informed* level (0%). However, in the post-test results of the intervention group, there was a critical decrease in the number of *naïve* students (40%) and significant increases in the number of *mixed* (51.9%) and *informed* (8.1%) students. For example, the quotations of student # 8 in the 7th grade of the intervention group are presented below. It was observed that the student had some partially correct ideas about the difference between data and evidence before the application, but he could express these ideas more clearly after the intervention.

> ***[Intervention G. 7th Grade Student #8, Pre-Test, and Interview]:*** *"It is different. Data is information that people collect about something. Evidence is, for example, the clues left at a crime scene to find the culprit, so evidence. It can be close, but evidence is to prove something; data is to determine the answer."* ***(mixed)***

> ***[Intervention G. 7th Grade Student #8, Post-test, and Interview]:*** *"I think they are different. Data is the information we have to investigate a topic, the information we have about the topic. Evidence is using the information we have to prove an event or an issue. That is why I think they are different."* ***(informed)***

The Mann-Whitney U Test posttest results shown in Table 6 reveal no significant difference between the intervention and control groups regarding this theme (U=4814.000, p=0.497, p>0.05).

*8. Explanations are developed using a combination of data and available information (SI-8)*

The pre-test results of the SI-8 aspect were very similar for both groups. Accordingly, students in the intervention group were *naïve* (91.3%), *mixed* (8%), and *informed* (0.7%), while students in the control group were *naïve* (85.7%), *mixed* (14.3%), and *informed* (0%). After the intervention, it was observed that the post-test results differed. Accordingly, there was a decrease in the percentage of *naïve* students in the intervention group (70.4%) and significant increases in the number of *mixed* (23%) and *informed* (6.7%) students. On the other hand, in the control group, there was a slight decrease in the number of *naïve* (82.7%) and *mixed* (17.3%) students, and no students at the *informed* level were observed.

For example, two quotations from two 5th grade students in two different intervention groups who developed their views at different levels are presented below. It is seen that student #22 could not make a reasoning or had no knowledge about the concept before the intervention, but after the intervention, she reasoned over the visuals and formed some ideas about the research processes.

> ***[Intervention G. 5th Grade Student #22, Pre-test, and Interview]:*** *"7a: Because they found fossils of the other one walking. Because according to picture 2, they cannot walk like that. 7b: I do not know."* ***(naïve)***

> ***[Intervention G. 5th Grade Student #22, Posttest, and Interview]:*** *"7a: Because in Picture 1 his spine is more regular. In this one (in Picture 2) his ribs are lower. 7b: By doing research themselves."* ***(mixed)***

Another student, #28, like the previous participant, did not have a correct understanding of the subject before the implementation but developed a high level of understanding, especially after the implementation.

> ***[Intervention G. 5th Grade Student #28, Pre-Test, and Interview]:*** "*7a: It could be because he stands on his feet. I think they saw one as appropriate, but I see both. 7b: From sources.*" ***(naïve)***
>
> ***[Intervention G. 5th Grade Student #28, Posttest, and Interview]:*** "*7a: I also think the first picture. Because I wrote something in the description underneath: It seemed wrong to me here (second one). Because I think short parts, short bones should be in the front. Because the back cannot carry it. I think those small parts can't carry it if it is in the back. His spine is more organized than his. In this one, his ribs are down. 7b: I think they can reach information by doing research themselves, asking scientists, researching in encyclopedias, books, and searching on websites.*" ***(informed)***

The Mann-Whitney U Test posttest results shown in Table 6 show *a significant difference* between the intervention and control groups in the context of this theme in favor of the intervention groups ($U=4381.500$, $p=0.033$, $p<0.05$). The next section will analyze grade level differences in the context of intervention groups and intervention-control group differences specific to levels.

***Findings of the Research Question 2: Is there a difference between 5th, 6th, and 7th grade middle school students' understandings of scientific inquiry, who were taught with Creative Problem-Solving Modules Enriched with the History of Science and who were taught with current science curriculum, by grade level?***

Pre- and post-test findings for the intervention and control group students are presented descriptively in Table 7 separately by grade level. The findings according to the grade levels in the context of aspects are explained below.

*1. Scientific research always starts with a question but does not necessarily test a hypothesis (SI-1)*

Specific to the SI-1 aspect, it is seen that most students in all grade levels in the intervention groups were at the *naïve* level. In this context, the most *naïve* students were recorded as 7$^{th}$ graders (90.7%) and then 5$^{th}$ graders (81.8%). When the control group was analyzed by grade level, it was observed that the highest number of *naïve* students was in the 7$^{th}$ grade, with similar rates. When the posttest results of the intervention group were analyzed after the application, it was determined that the number of students at the *naïve* level decreased in both the 5$^{th}$ and 7$^{th}$ graders, and these students increased to the *mixed* level. On the other hand, in the control group classes where the science curriculum was implemented, the posttest results showed that the proportion of students at the *naïve* level did not decrease in grade levels. The grade level that showed the most improvement in this aspect was the 7$^{th}$ graders, where the interventions were carried out, followed by the 5$^{th}$ graders.

*2. There is no uniform/step-by-step way to conduct scientific research (SI-2)*

When the pre-test data of the SI-2 aspect were analyzed, it was observed that the highest number of *naïve* students in the intervention groups was 5$^{th}$ graders (90.9%), 6$^{th}$ graders (86.2%) and 7$^{th}$ graders (85.5%), and that the number of *naïve* students was similar in terms of grade levels. In the control group, it was ranked as 6$^{th}$ grade (92.6%), 7$^{th}$ grade (90.5%), and 5$^{th}$ grade (79.3%). After the intervention, it was observed that the best improvement in the intervention group students was at the 7$^{th}$ grade level (51.9%) in terms of the decrease in *naïve* level students, and similarly, the number of *mixed* level students was the highest in the 7$^{th}$ grades (48.1%). It was determined that the improvement rates of the 5$^{th}$ and 6$^{th}$ graders in the intervention group were close to each other. In the control group, where the MoNE science curriculum was implemented, according to the post-test results, it was observed that the best improvement was at the 7$^{th}$ grade level, but there was no significant improvement at the 5$^{th}$ and 6$^{th}$ grade levels.

*3. Scientific research processes are shaped by the question asked (SI-3)*

In the SI-3 aspect, the students in the *naïve* level of the intervention groups were 7th grade (81.5%), 5th grade (58.2%), and 6th grade (55.2%). The classes with the highest level of development after the interventions were 7th and 5th grade, with a critical decrease in the *naïve* level and a significant increase in the *mixed* level. The control group pretest data showed that there was no significant difference between the classes in terms of grade levels. On the other hand, it was observed that 6th graders improved at all levels due to the MoNE science program activities.

*4. All scientists applying the same processes may not reach the same conclusions (SI-4)*

In this aspect, the intervention group students' pre-test data showed very little difference between the classes. After the interventions, it was observed that the 7th graders in the intervention group positively differed from the other grade levels at all levels. The pre-test data of the control group showed that the highest level of *naive* students was 6th grade (63%), followed by 5th grade (58.6%). In the control group, the opinions of the 6th graders changed positively after the MoNE science program activities, while this development was not observed in other grade levels.

*5. Scientific research processes can have an impact on results (SI-5)*

In the SI-5 aspect, it was observed that the students in the *naive* level in the intervention groups were in 7th grade (63%), 6th grade (55.2%), and 5th grade (49.1%). After the interventions, it was observed that the 7th graders in the intervention group positively differentiated at all levels in the other grade levels. The pre-test data of the control group revealed that the situation of the 6th grade students in the control group was positively different from the other grade levels at the beginning. After the science lesson interventions, a significant improvement in the control group was observed in the 7th grade students, with a decrease in the number of *naive* students and an increase in the number of mixed students.

*6. Research results should be consistent with the data obtained (SI-6)*

In the SI-5 aspect, the students in the *naive* level in the intervention groups were 5th grade (63.6%), 6th grade (58.6%), and 7th grade (44.4%). After the interventions, significant improvements were observed at each grade level in the intervention group. In particular, it was observed that the best improvement was observed in the 7th grade (24.1%) and 6th grade (21.9%), with an increase in the number of students at the *informed* level. The pre-test data of the control group showed that the situation of the 7th grade students in the control group differed from the other grade levels at the beginning, with the highest proportion of students at the *naïve* level (61.9%) among the other grade levels. After the MoNE science program activities, it was observed that no significant changes were observed in the 5th and 6th grades of the control group, but the 7th grades were positively differentiated.

**Table 7.** Descriptive Comparison of the Changes in the Pre-Test - Posttest Scientific Inquiry Conceptions of Intervention and Control Groups by Grade Level

| Aspect of Scientific Inquiry | Grade Level | | Intervention Groups | | | | | | | | | Control Groups | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pre-Test | | | | Post-Test | | | | | Pre-Test | | | | Post-Test | | | |
| | | | Naïve | Mixed | Informed | Total | Naïve | Mixed | Informed | Total | | Naïve | Mixed | Informed | Total | Naïve | Mixed | Informed | Total |
| **SI-1** | **5th** | N | 45 | 10 | 0 | 55 | 34 | 15 | 0 | 49 | N | 23 | 5 | 1 | 29 | 23 | 6 | 0 | 29 |
| | | % | 81,8 | 18,2 | 0 | 100 | 69,4 | 30,6 | 0 | 100 | % | 79,3 | 17,2 | 3,4 | 100 | 79,3 | 20,7 | 0 | 100 |
| | **6th** | N | 19 | 10 | 0 | 29 | 21 | 11 | 0 | 32 | N | 20 | 7 | 0 | 27 | 18 | 7 | 0 | 25 |
| | | % | 65,5 | 34,5 | 0 | 100 | 65,6 | 34,4 | 0 | 100 | % | 74,1 | 25,9 | 0 | 100 | 72 | 28 | 0 | 100 |
| | **7th** | N | 49 | 5 | 0 | 54 | 35 | 19 | 0 | 54 | N | 17 | 4 | 0 | 21 | 18 | 3 | 0 | 21 |
| | | % | 90,7 | 9,3 | 0 | 100 | 64,8 | 35,2 | 0 | 100 | % | 81 | 19 | 0 | 100 | 85,7 | 14,3 | 0 | 100 |
| | *Total* | N | **113** | **25** | **0** | **138** | **90** | **45** | **0** | **135** | N | **60** | **16** | **1** | **77** | **59** | **16** | **0** | **75** |
| | | % | **81,9** | **18,1** | **0** | **100** | **66,7** | **33,3** | **0** | **100** | % | **77,9** | **20,8** | **1,3** | **100** | **78,7** | **21,3** | **0** | **100** |
| **SI-2** | **5th** | N | 50 | 5 | 0 | 55 | 34 | 15 | 0 | 49 | N | 23 | 5 | 1 | 29 | 27 | 2 | 0 | 29 |
| | | % | 90,9 | 9,1 | 0 | 100 | 69,4 | 30,6 | 0 | 100 | % | 79,3 | 17,2 | 3,4 | 100 | 93,1 | 6,9 | 0 | 100 |
| | **6th** | N | 25 | 4 | 0 | 29 | 21 | 11 | 0 | 32 | N | 25 | 2 | 0 | 27 | 17 | 8 | 0 | 25 |
| | | % | 86,2 | 13,8 | 0 | 100 | 65,6 | 34,4 | 0 | 100 | % | 92,6 | 7,4 | 0 | 100 | 68 | 32 | 0 | 100 |
| | **7th** | N | 43 | 11 | 0 | 54 | 28 | 26 | 0 | 54 | N | 19 | 2 | 0 | 21 | 18 | 3 | 0 | 21 |
| | | % | 85,5 | 14,5 | 0 | 100 | 51,9 | 48,1 | 0 | 100 | % | 90,5 | 9,5 | 0 | 100 | 85,7 | 14,3 | 0 | 100 |
| | *Total* | N | **118** | **20** | **0** | **138** | **83** | **52** | **0** | **135** | N | **67** | **9** | **1** | **77** | **62** | **13** | **0** | **75** |
| | | % | **85,5** | **14,5** | **0** | **100** | **61,5** | **38,5** | **0** | **100** | % | **87** | **11,7** | **1,3** | **100** | **82,7** | **17,3** | **0** | **100** |
| **SI-3** | **5th** | N | 32 | 21 | 2 | 55 | 10 | 38 | 1 | 49 | N | 9 | 19 | 1 | 29 | 9 | 16 | 4 | 29 |
| | | % | 58,2 | 38,2 | 3,6 | 100 | 20,4 | 77,6 | 2 | 100 | % | 31 | 65,5 | 3,5 | 100 | 31 | 55,2 | 13,8 | 100 |
| | **6th** | N | 16 | 13 | 0 | 29 | 7 | 20 | 5 | 32 | N | 10 | 17 | 0 | 27 | 5 | 19 | 1 | 25 |
| | | % | 55,2 | 44,8 | 0 | 100 | 21,9 | 62,5 | 15,6 | 100 | % | 37 | 63 | 0 | 100 | 20 | 76 | 4 | 100 |
| | **7th** | N | 44 | 9 | 1 | 54 | 24 | 23 | 7 | 54 | N | 8 | 13 | 0 | 21 | 10 | 10 | 1 | 21 |
| | | % | 81,5 | 16,7 | 1,9 | 100 | 44,4 | 42,6 | 13 | 100 | % | 38,1 | 61,9 | 0 | 100 | 47,6 | 47,6 | 4,8 | 100 |
| | *Total* | N | **92** | **43** | **3** | **138** | **41** | **81** | **13** | **135** | N | **27** | **49** | **1** | **77** | **24** | **45** | **6** | **75** |
| | | % | **66,7** | **31,2** | **2,2** | **100** | **30,4** | **60** | **9,6** | **100** | % | **35,1** | **63,6** | **1,3** | **100** | **32** | **60** | **8** | **100** |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SI-4** | **5th** | N | 32 | 23 | 0 | 55 | 26 | 21 | 2 | 49 | N | 17 | 11 | 1 | 29 | 16 | 11 | 2 | 29 |
| | | % | 58,2 | 41,8 | 0 | 100 | 53,1 | 42,9 | 4,1 | 100 | % | 58,6 | 37,9 | 3,4 | 100 | 55,2 | 37,9 | 6,9 | 100 |
| | **6th** | N | 15 | 14 | 0 | 29 | 18 | 12 | 2 | 32 | N | 17 | 10 | 0 | 27 | 8 | 16 | 1 | 25 |
| | | % | 51,7 | 48,3 | 0 | 100 | 56,3 | 37,5 | 6,3 | 100 | % | 63 | 37 | 0 | 100 | 32 | 64 | 4 | 100 |
| | **7th** | N | 31 | 21 | 2 | 54 | 13 | 25 | 16 | 54 | N | 7 | 14 | 0 | 21 | 7 | 14 | 0 | 21 |
| | | % | 57,4 | 38,9 | 3,7 | 100 | 24,1 | 46,3 | 29,3 | 100 | % | 33,3 | 66,7 | 0 | 100 | 33,3 | 66,7 | 0 | 100 |
| | *Total* | N | **78** | **58** | **2** | **138** | **57** | **58** | **20** | **135** | N | **41** | **35** | **1** | **77** | **31** | **41** | **3** | **75** |
| | | % | **56,5** | **42** | **1,4** | **100** | **42,2** | **43** | **14,8** | **100** | % | **53,2** | **45,5** | **1,3** | **100** | **41,3** | **54,7** | **4** | **100** |
| **SI-5** | **5th** | N | 27 | 28 | 0 | 55 | 35 | 19 | 1 | 55 | N | 10 | 18 | 1 | 29 | 8 | 21 | 0 | 29 |
| | | % | 49,1 | 50,9 | 0 | 100 | 63,6 | 34,5 | 1,8 | 100 | % | 34,5 | 62,1 | 3,4 | 100 | 27,6 | 72,4 | 0 | 100 |
| | **6th** | N | 16 | 13 | 0 | 29 | 17 | 11 | 1 | 29 | N | 5 | 22 | 0 | 27 | 8 | 17 | 0 | 25 |
| | | % | 55,2 | 44,8 | 0 | 100 | 58,6 | 37,9 | 3,4 | 100 | % | 18,5 | 81,5 | 0 | 100 | 32 | 68 | 0 | 100 |
| | **7th** | N | 34 | 19 | 1 | 54 | 24 | 25 | 5 | 54 | N | 10 | 11 | 0 | 21 | 7 | 14 | 0 | 21 |
| | | % | 63 | 35,2 | 1,9 | 100 | 44,4 | 46,3 | 9,3 | 100 | % | 47,6 | 52,4 | 0 | 100 | 33,3 | 66,7 | 0 | 100 |
| | *Total* | N | **77** | **60** | **1** | **138** | **76** | **55** | **7** | **138** | N | **25** | **51** | **1** | **77** | **23** | **52** | **0** | **75** |
| | | % | **55,8** | **43,5** | **0,7** | **100** | **55,1** | **39,9** | **5,1** | **100** | % | **32,5** | **66,2** | **1,3** | **100** | **30,7** | **69,3** | **0** | **100** |
| **SI-6** | **5th** | N | 35 | 19 | 1 | 55 | 22 | 26 | 1 | 49 | N | 8 | 19 | 2 | 29 | 11 | 18 | 0 | 29 |
| | | % | 63,6 | 34,5 | 1,8 | 100 | 44,9 | 53,1 | 2 | 100 | % | 27,6 | 65,5 | 6,9 | 100 | 37,9 | 62,1 | 0 | 100 |
| | **6th** | N | 17 | 11 | 1 | 29 | 13 | 12 | 7 | 32 | N | 10 | 17 | 0 | 27 | 10 | 12 | 3 | 25 |
| | | % | 58,6 | 37,9 | 3,4 | 100 | 40,6 | 37,5 | 21,9 | 100 | % | 37 | 63 | 0 | 100 | 40 | 48 | 12 | 100 |
| | **7th** | N | 24 | 25 | 5 | 54 | 11 | 30 | 13 | 54 | N | 13 | 7 | 1 | 21 | 8 | 7 | 6 | 21 |
| | | % | 44,4 | 46,3 | 9,3 | 100 | 20,4 | 55,6 | 24,1 | 100 | % | 61,9 | 33,3 | 4,8 | 100 | 38,1 | 33,3 | 28,6 | 100 |
| | *Total* | N | **76** | **55** | **7** | **138** | **46** | **68** | **21** | **135** | N | **31** | **43** | **3** | **77** | **29** | **37** | **9** | **75** |
| | | % | **55,1** | **39,9** | **5,1** | **100** | **34,1** | **50,4** | **15,6** | **100** | % | **40,3** | **55,8** | **3,9** | **100** | **38,7** | **49,3** | **12** | **100** |
| **SI-7** | **5th** | N | 33 | 22 | 0 | 55 | 18 | 30 | 1 | 49 | N | 11 | 17 | 1 | 29 | 13 | 16 | 0 | 29 |
| | | % | 60 | 40 | 0 | 100 | 36,7 | 61,2 | 2 | 100 | % | 37,9 | 58,6 | 3,4 | 100 | 44,8 | 55,2 | 0 | 100 |
| | **6th** | N | 13 | 16 | 0 | 29 | 18 | 14 | 0 | 32 | N | 9 | 18 | 0 | 27 | 5 | 20 | 0 | 25 |
| | | % | 44,8 | 55,2 | 0 | 100 | 56,3 | 43,8 | 0 | 100 | % | 33,3 | 66,7 | 0 | 100 | 20 | 80 | 0 | 100 |
| | **7th** | N | 28 | 26 | 0 | 54 | 18 | 26 | 10 | 54 | N | 7 | 14 | 0 | 21 | 4 | 17 | 0 | 21 |
| | | % | 51,9 | 48,1 | 0 | 100 | 33,3 | 48,1 | 18,5 | 100 | % | 33,3 | 66,7 | 0 | 100 | 19 | 81 | 0 | 100 |
| | *Total* | N | **74** | **64** | **0** | **138** | **54** | **70** | **11** | **135** | N | 27 | 49 | 1 | 77 | 22 | 53 | 0 | 75 |
| | | % | **53,6** | **46,4** | **0** | **100** | **40** | **51,9** | **8,1** | **100** | % | **35,1** | **63,6** | **1,3** | **100** | **29,3** | **70,7** | **0** | **100** |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SI-8** | **5th** | N | 54 | 1 | 0 | 55 | 40 | 9 | 0 | 49 | N | **24** | **5** | **0** | **29** | **27** | **2** | **0** | **29** |
| | | % | 98,2 | 1,8 | 0 | 100 | 81,6 | 18,4 | 0 | 100 | % | 82,8 | 17,2 | 0 | 100 | 93,1 | 6,9 | 0 | 100 |
| | **6th** | N | 25 | 3 | 1 | 29 | 29 | 3 | 0 | 32 | N | 23 | 4 | 0 | 27 | 20 | 5 | 0 | 25 |
| | | % | 86,2 | 10,3 | 3,4 | 100 | 90,6 | 9,4 | 0 | 100 | % | 85,2 | 14,8 | 0 | 100 | 80 | 20 | 0 | 100 |
| | **7th** | N | 47 | 7 | 0 | 54 | 26 | 19 | 9 | 54 | N | 19 | 2 | 0 | 21 | 15 | 6 | 0 | 21 |
| | | % | 87 | 13 | 0 | 100 | 48,1 | 35,2 | 16,7 | 100 | % | 90,5 | 9,5 | 0 | 100 | 71,4 | 28,6 | 0 | 100 |
| | *Total* | N | **126** | **11** | **1** | **138** | **95** | **31** | **9** | **135** | N | **66** | **11** | **0** | **77** | **62** | **13** | **0** | **75** |
| | | % | **91,3** | **8** | **0,7** | **100** | **70,4** | **23** | **6,7** | **100** | % | **85,7** | **14,3** | **0** | **100** | **82,7** | **17,3** | **0** | **100** |

*7. Scientific evidence is not the same as scientific data (SI-7)*

In this aspect, the intervention group students' pre-test data showed very little difference between the classes. After the interventions, it was observed that especially the 7th and 5th grade students in the intervention group differed positively. Similarly, the pre-test data of the control group showed no significant difference between the classes regarding grade levels. In this group, after the interventions, especially the 7th grade students differed from the other grade levels with an increase in the *mixed* level.

*8. Explanations are developed using a combination of data and available information (SI-8)*

In the pre-tests in the SI-8 aspect, it was observed that students in both intervention and control groups were at the *naive* level at an average of 80% in all grade levels, and there were no significant differences between the grade levels. After the interventions, it was determined that the intervention group's 7th and 5th grade students showed increased development. The posttest data of the control group, on the other hand, showed that the program implementations in this aspect enabled students to improve, especially at the 6th and 7th grade levels.

## Conclusion and Discussion

The relevant literature has revealed that students' scientific inquiry understandings at the middle school level in Türkiye are inadequate (Doğan et al., 2020; Lederman et al., 2019, 2021; Senler, 2015) and that curriculum reforms (MoNE, 2005, 2013, 2018) have not been effective in supporting the development of these conceptions. In this regard, the current science curriculum needs to be organized in a modular structure where students can find creative solutions to real-life problems with inquiry, collaboration, reflection, and experience the process of creating scientific knowledge, and learn the history of science at the same time (Doğan, 2017; Doğan et al., 2020; Özer & Sarıbaş, 2023). At this point, in line with the stated need and with the ultimate goal nurturing scientifically literate individuals, it was aimed to develop the understandings of 5th ,6th, and 7th grade middle school students on scientific inquiry with long-term and innovative *Creative Problem-Solving Modules Enriched with the History of Science* and to compare their effectiveness with the current science curriculum.

*Research Question 1*

Within the scope of the 1st research question of the study, the effect of the implementation of the *Creative Problem-Solving Modules Enriched with the History of Science Modules* on the eight aspects of scientific inquiry understandings in the intervention groups for one year was investigated and compared with the control groups. As stated in the findings section, it was observed that the change in the views of the intervention and control groups, which constitute the entire study group, regarding scientific inquiry was statistically significant in the aspect of SI-2 (*There is no uniform/step-by-step way to carry out scientific investigations*) and SI-8 (*Explanations are developed by using the data obtained and existing knowledge together*). However, in the context of all aspects, the descriptive statistics of the posttest results showed that the students with the *informed* level proportionally were in the intervention groups. In this context, the one-year implementation of *Creative Problem-Solving Modules Enriched with the History of Science* led to the emergence of students at the *informed* level in 6 of the eight aspects of scientific inquiry (SI-3, SI-4, SI-5, SI-6, SI-7, and SI-8). In addition, it was determined that the students in the intervention group were the ones who decreased the most in the percentage of students who were *naïve* at the beginning. In this context, in the intervention groups, there were no students at the *informed* level only in the aspects of "*Scientific investigations always start with a question but do not necessarily test a hypothesis* (SI-1)" and "*There is no uniform/step-by-step way to carry out scientific investigations* (SI-2')". In contrast, in the control group, it was determined that there were no students at the *informed* level in 5 of the eight scientific inquiry aspects (SI-1, SI-2, SI-5, SI-7, SI-8).

In particular, the aspects such as SI-5 (*Inquiry process affects the results*), SI-7 (*Scientific data and scientific evidence are not the same things)*, SI-8 (*Explanations are put forward by combining the data obtained and our existing knowledge*), which are difficult to develop even in pre-service teachers (Doğan, 2017; Özer & Sarıbaş, 2023), were found to developed at the *informed* level only in the intervention group students (in the posttest). Moreover, although the lowest percentage of the *naïve* level was found in the intervention group of students before the interventions, based on these findings, it was concluded that the *Creative Problem-Solving Modules Enriched with the History of Science* interventions were more effective in developing middle school students' understandings on scientific inquiry with the activities it included compared to the current science curriculum activities.

When the results were examined in detail, the pre-test results showed that although the control group's pre-test level was better than the intervention group in the aspect SI-5 (*Inquiry process affects the results*), the post-test results showed that the opinions at the *informed* level were higher in the intervention group and the development in the control group was insufficient. This aspect questions the views on the role of methodology and personal characteristics in the process of scientific research and scientific knowledge production. In the *Creative Problem-Solving Modules Enriched with the History of Science* learning environments, the students realized what knowledge, methods, and tools are used in open-ended problem solving and how inferences are made in a group-specific and authentic way for one year. Since the open-ended problem situations presented have more than one correct answer by nature, students have gained the experience that both methodological and individual factors affect and change the outcome during the inquiry process. In addition, it is clear that reflection-based discussions about the history of science positively affected scientific inquiry understandings. In this context, the results of the study conducted by Doğan (2017) with pre-service teachers for one semester using problem-based learning and history of science activities revealed that the views on the aspect of the inquiry process affect the results (SI-5) showed the most improvement. Similarly, Çetin (2021) found that the most positive development was in the views regarding this aspect in her study in which inquiry-based chemistry laboratory activities were applied to high school (9$^{th}$ grade) students.

Another prominent result was related to the aspect SI-7 (*Scientific data and scientific evidence are not the same thing*). The pre-test results of the study show that both groups had difficulty distinguishing between data and evidence within the scope of the SI-7 aspect. Although the results of the studies conducted with pre-service teachers indicated that they were better able to distinguish between data and evidence (Doğan, 2017; Özer & Sarıbaş, 2023; Erdaş-Kartal & Mesci 2022; Mesci et al., 2019), many studies have shown that middle school students cannot distinguish between data and evidence scientifically (Bolu, 2017; Doğan et al., 2020; Lederman et al., 2019, 2021). In the related literature, the difficulty in understanding the difference between data and evidence is attributed to the fact that these two concepts are not very clear in many languages. In this context, Gyllenpalm, Rundgren, Lederman, and Lederman (2022) emphasized that this situation is also encountered in Swedish. It is thought that this result is due to the grammatical structure of Turkish, especially in young age groups, and that the frequent use of scientific data and evidence interchangeably in various media tools (TV, online platforms, news) causes misconceptions (Özer, Doğan, Yalaki, İrez, & Çakmakçı, 2021). Studies in literature show that opinions on this aspect cannot develop when it is not accompanied by a reflection-based inquiry process (Lederman, 2019; Schwartz & Crawford, 2004; Sarışan-Tungaç, Yaman, & Bal-İncebacak, 2018). Indeed, the results of the posttests in the control group classes also showed that students' understandings on this aspect could not be developed. For this reason, it is recommended that teachers should lead students for reflection, which is one of the most important processes for the development of scientific inquiry and science literacy, during and after the implementation in societies with such language structure (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Erdaş-Kartal & Mesci, 2022; Schwartz & Crawford, 2004).

It was reported that students were able to distinguish scientific data and evidence in the inquiry processes with explicit reflection under teacher mentoring (Bolu, 2017; Leblebicioğlu et al., 2019) and argumentation-based practices (Peten, 2022). Within the scope of *Creative Problem-Solving Modules Enriched with the History of Science*, students were asked to specify what information they would need to solve the problem and collect data in each scenario. In addition, they were asked to make inferences from the data and information they obtained, and at the end of the process, they were asked to explain in writing or orally how they solved the problem by transforming the information into evidence. In addition, within the scope of the various history of science activities in each module, students were asked to find out what kind of data and information the scientists related to the subject benefited from and to make reflections based on the discussion at the end of the process. The increase in the number of *informed* students, especially in the intervention group students, thanks to these activities, which aimed to help students understand the difference between the concepts of data and evidence, can be associated with the content of the interventions in this context.

In addition, it is thought necessary to highlight the development related to the SI-8 (*Explanations are put forward by combining the data obtained and our current knowledge*) aspect, in which the students had the highest level of *naive* understandings in the pre-test findings. This finding was also found in the results of Doğan et al.'s (2020) descriptive study. However, the sharp increase in the number of *informed* students in the intervention group after the implementation and the lack of development in the control group regarding this aspect can be explained by the effect of the *Creative Problem-Solving Modules Enriched with the History of Science*. Doğan et al. (2020) emphasized the necessity of inquiry-based and argumentation-oriented classroom practices in which students make inferences and explanations from the data and information that they obtain individually or as a group to develop understandings regarding the SI-8 aspect. In this study, as shown in Table 3, each module intervention included processes in which students were expected to collect data, analyze and construct explanations for open-ended problem situations similar to those they may encounter in daily life by aiming the development of many scientific inquiry aspects simultaneously. Especially during the one-year period, expecting students to construct explanations for defining problems in each module and to make reflection-based explanations in the history of science activities is thought to be effective in developing students' understandings on this aspect.

*Research Question 2*

Within the scope of the 2nd research question of the study, the effect of the module interventions, which were implemented in the intervention groups for one year, on the eight aspects of scientific inquiry aspects was investigated according to the grade level and compared with the control groups. The results showed that in the intervention groups in which the modules were implemented, the highest improvement in the aspects of scientific inquiry was observed at the 7th grade level. This improvement was especially seen in the eight aspects of scientific inquiry, with a significant decrease in the number of students at the *naive* level. Similarly, at the end of the implementation, the number of knowledge levels in six of the eight aspects of scientific inquiry (SI-3, SI-4, SI-5, SI-6, SI-7, and SI-8) was observed in the 7th grade students in the intervention group. Another group in which the intervention positively affected scientific inquiry understandings was the 5th graders. This development was observed in seven of the eight aspects of scientific inquiry (SI-1, SI-2, SI-3, SI-4, SI-6, SI-7, and SI-8), with a significant decrease in the number of *naive* students. In addition, it was found that the number of students at the *informed* level of 5th grade students increased significantly in SI-4, SI-6, and SI-7 aspects. At the 6th grade level, it was observed that the interventions positively supported the development of SI-2, SI-3, and SI-6 aspects. On the other hand, it was determined that the change according to the grade level in the control group of students who studied with the curriculum activities differed according to the scientific inquiry aspect. In this regard, it was observed that the number of *naïve* level students increased (e.g., SI-1: 7th grade, SI-2: 5th grade, SI-3: 7th grade, SI-6: 5th grade and 6th grade, SI-7: 5th grade, SI-8: 5th grade) or there was no change (SI-1: 5th grade, SI-3: 5th grade, SI-4: 7th grade) regardless of the grade level context.

In this study, the grade level with the highest level of scientific inquiry understanding and inclination towards improvement was reported as the 6th graders. This finding is considered to be quite consistent with the results of the control group of the study. As a matter of fact, within the scope of this study, it was determined that the science curriculum practices in the control group had a partially positive effect on the development of six of the eight scientific inquiry aspects (SI-1, SI-2, SI-3, SI-4, SI-7, and SI-8), especially at the 6th grade level. In this context, it is concluded that science curriculum activities have a limited effect on developing understandings on scientific inquiry. However, it is important to emphasize the positive impact of the *Creative Problem-Solving Modules Enriched with the History of Science* interventions on many scientific inquiry aspects of students at all grade levels. As Bolu (2017) and Doğan et al. (2020) stated, the development in scientific inquiry levels according to the grade level can be possible with learning environments enriched with inquiry-based problem-solving and practices that students experience by doing and experiencing based on reflecting the scientific process. *Creative Problem-Solving Modules Enriched with the History of Science*, the effectiveness of which was tested on intervention groups, are the learning environments that include these features (Özer & Doğan, 2022).

Improving the understandings on scientific inquiry, an important dimension of science literacy measured in international exams (e.g., PISA and TIMSS and national exams such as ABIDE) forms the basis for the development of future scientists and the emergence of an informed society. Thus, instead of constantly reforming the content of the science curriculum, the inadequacy of which has been reported in international and national exams and many studies, the necessity of structuring the curriculum in a modular way within the framework of acquisitions that offers students the opportunity to experience the process of inquiry, investigation, open-ended problem solving, creative problem solving, data collection, and analysis has been revealed by the results of this study.

## Recommendations

Recommendations developed according to the results of the study are listed below:

1. Experimental studies in the field of understandings of scientific inquiry are limited. It has been demonstrated by the results of this study that different scientific inquiry aspects can be developed for each grade level. However, there is a need for more in-depth studies on which aspects can be developed with what kind of special interventions specific to grade levels.
2. Questionnaires that include paper-pencil writing features on answering open-ended questions, especially with young age groups such as middle school level, can sometimes be challenging for students. Thus, as used in this study, it is recommended to conduct focus group or individual interviews as well as questionnaires in the evaluation of structures such as scientific inquiry and the nature of science, as it gives students the chance to explain their answers and elaborate the responses.
3. In this study, the entire intervention process took place in a learning environment in which the teachers took the role of guide-mentor in the classroom, and it takes time and experience to reflect such role changes in classroom practices. As stated in the methodology section, the two science teachers included in the study were teachers who have experience in their field and have high academic degrees. However, they needed professional support from the authors throughout the study process in order to effectively apply the newly developed experimental interventions in the classroom. In this context, informative meetings were held with them before and after each intervention, their opinions and feedback were received, and training was given to them. Therefore, teachers should be constantly supported by professional development programs to carry out the classroom practices of these and similar new practices and methods to be developed effectively.

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# Appendices

**Appendix 1.** Indicators of Modules' Applied in the Study and Targeted SI Aspects

| Grade Level | Science Curriculum (MONE 2013, 2018) Unit, Subject-Topic, Standards, and Activities | Creative Problem-Solving Modules Enriched with the History of Science | Duration | Targeted SI Aspect (SI) |
|---|---|---|---|---|
| **5th Grade, 6th Grade** | **5th Grade:**<br>Unit 3: Phase Changes of Matter<br>Subject: F. 5.3.1. Phase Changes (MONE, 2013)<br><br>Unit 4: Matter and Change<br>Subject: F. 5.4.1. Phase Changes (MONE, 2018)<br>Activity 3.1. Melting and freezing<br>Activity 3.2. Evaporation and condensation<br>Activity 3.3. Sublimation and deposition<br><br>**6th Grade:**<br>Unit 3<br>Section 1: Structure of Matter<br>Section 2: Physical and Chemical Changes<br>Subject: F. 6.3.2. Physical and Chemical Changes (MONE, 2013)<br>F. 6.4.1. Structure of Matter (MONE, 2018)<br>Activity 3.3. Let's observe the movements of particles<br>Activity 3.6. Matters are changing | Transfer of Maraş Ice Cream to World Module<br>*Problem Scenario:* Meeting of Maraş Ice Cream with the World<br>*History of Science:* Physicist Decoding Nature's Language: Thorbjorn | 3 hours | SI 1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI 3-Inquiry procedures are guided by the questions asked- SI 3<br>SI 4-All scientists performing the same procedures may not get the same results<br>SI 5-Inquiry procedures can influence the results |

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|---|---|---|---|---|
| **5th Grade** | Unit 5: Get to Know the Living Things<br>Subject: F. 5.5.1. Introduction of the Living Things (MONE, 2013)<br><br>Unit 2: World of Living Things<br>Subject: F. 5.2.1. Introduction of the Living Things (MONE, 2018)<br>Activity 5.1. Observation of microscopic living things<br>*Reading Text*: Historical background<br>Activity 5.2. What parts do flowering plants consist of<br>Activity 5.3. Let's observe the plants around us<br>Activity 5.4. Observing in nature | Classification or Non-Classification of the Living Things Module<br>*Problem Scenario:* Solve the Confusion, Find and Classify the Appropriate Planet<br>*History of Science:* History of Classification | 4 hours | SI-1- Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-4-All scientists performing the same procedures may not get the same results |
| **5th Grade, 7th Grade** | **5th Grade:**<br>Unit 5: Get to Know the Living Things<br>Subject: F. 5.5.2. Human and Environment Relations (MONE, 2013)<br><br>Unit 6: Human and Environment<br>Subject F.5.6.2. Human and Environment Relations (MONE, 2018)<br>Activity 5.5. Is our environment changing?<br>Activity 5.6. Let's observe air pollution<br><br>**7th Grade:**<br>Unit 5- Human and Environment Relations<br>Section 4-Household Waste and Recycle<br>Subject: F.7.3.5. Household Waste and Recycle (MONE, 2013)<br>F.7.4.5. Household Waste and Recycle (MONE, 2018)<br>Activity 10. Let's separate the garbage<br>Activity 11. Environment Club | Recycling Data Analysis Module<br>*Problem Scenario:* Garbage cannot be composed?<br>*Problem Scenario:* Recycling Data Analysis of Countries: Action Plan to Increase Recycling in Turkey<br>*History of Science:* History of Recycling and Recovery | 3 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-2-There is no single set or sequence of steps followed in all investigations<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-4-All scientists performing the same procedures may not get the same results<br>SI-6-Research conclusions must be consistent with the data collected<br>SI-7- Scientific data are not the same as evidence<br>SI-8-Explanations are developed from a combination of collected data and what is already known |

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| **5th Grade, 6th Grade, 7th Grade** | **5th Grade:**<br>Unit 7: The Mystery of the Earth's Crust, Fossils bearing traces of the past, Fossil science, Fossil Types F. 5.7.1. What's in the Earth's Crust (MONE, 2013)<br><br>Unit 1: Sun, Earth, and Moon<br>Subject: F.5.1.5. / 5.6.3. Destructive Natural Phenomenon (MONE, 2018)<br>Activity 7.3. Let's make our own fossil<br>*Reading Text*: There is a letter from a paleontologist!<br><br>**6th Grade**<br>Unit 1: Body Systems<br>Section 2: Muscular and Skeletal System<br>Subject: F.6.1.2./ F. 6.2.1. Muscular and Skeletal System<br>(MONE, 2013; 2018)<br>Activity 1.4. I'm getting to know my bones (*drawing*)<br>Activity. Prepare a poster on maintaining the health of muscular and skeletal System<br><br>**7th Grade:**<br>Unit 1 - Body Systems Health of Our Body System (Muscular and Skeletal System) ((MONE, 2013) | Little Paleontologists Search for Fossils! Module<br>*Problem Scenario:* Explore and Predict the Living!<br>*History of Science:*<br>The Story of Sue the T-rex | 4 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-4-All scientists performing the same procedures may not get the same results<br>SI-8-Explanations are developed from a combination of collected data and what is already known |
| **6th Grade** | Unit 1 - Body Systems<br>Section 4: Circulatory System<br>Subject F.6.1.4. Circulatory System (MONE, 2013)<br><br>Activity 1.7. I'm examining the structure of the heart (*Dissection*)<br>Activity 1.8. Who am I? (*Riddle*)<br>Activity 1.9. Showing the large and small blood circulation in the diagram<br>Activity 1.10. Blood donation | Circulatory System Module<br>*Problem Scenario*: Wheat Collection and Distribution Center: Large-Small Blood Circulation Modeling<br>*History of Science:*<br>Historical Background of Heart Studies | 5 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-8-Explanations are developed from a combination of collected data and what is already known |

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| **6th Grade** | Unit 4<br>Section 1. Reflection of Light<br>F.6.4.1. Reflection of Light (MONE, 2013)<br>F.7.5.3. Refraction of the Light and Lenses (MONE, 2018)<br>Activity 4.1. Drawing the rays<br>Activity 4.2. Smooth or diffuse reflection? | Periscope Adventures Module<br>*Problem Scenario:* Periscope Manager and Defective Submarine Periscope<br>*History of Science:* Satellite Working Principle and History of Artificial Satellites-Moons | 3 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-2-There is no single set or sequence of steps followed in all investigations<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-4-All scientists performing the same procedures may not get the same results<br>SI 5-Inquiry procedures can influence the results |
| **7th Grade** | Unit 2 - Force and Energy<br>Section 3 - Force, Work, Energy Relations, and Energy Transformations<br><br>Subject: F.7.2.3. / F. 7.3.2. Force, Work, Energy Relations (MONE, 2013; 2018)<br>Subject: F. 7.2.4. / F. 7.2.3. Energy Transformations (MONE, 2013; 2018)<br>Activity 4. In which situation it is considered as “work”?<br>Activity 5. Mass changes the magnitude of the energy of motion<br>Activity 6. What does gravitational potential energy depend on?<br>Activity 7. Elasticity Potential Energy<br>Activity 8. Energy Transformations Why did the kinetic energy decrease? | Kinetic, Potential Energy (Gravitational Potential Energy Elasticity Potential Energy) and Transformations Module<br>*Problem Scenario:* Asli's Car Problem<br>*Problem Scenario:* The Struggle of Taşkesti Villagers with Brave Hill<br>*Problem Scenario:* BoLUNAPARK Amusement and Energy Center<br>*History of Science:* History of Catapult and Making your own Catapult | 6 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-4-All scientists performing the same procedures may not get the same results<br>SI-8-Explanations are developed from a combination of collected data and what is already known |

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| **7th Grade** | Unit 5- Human and Environment Relations<br>Section 4-Chemical Industry in Türkiye<br>Subject F.7.3.6. / F.mone 8.4.6. Chemical Industry (MONE, 2013; 2018)<br><br>Activity 12. Let's research the chemical industry institutions in Turkey | Chemical Industry in Türkiye<br>Data Analysis Module<br>*Problem Scenario:* Regional Situation and Data Analysis in Turkey, Creating a Regional Solution Plan<br>*History of Science: :* Hope of Once: DDT | 2 hours | SI-1-Scientific investigations all begin with a question, but do not necessarily test a hypothesis<br>SI-2-There is no single set or sequence of steps followed in all investigations<br>SI-3- Inquiry procedures are guided by the questions asked<br>SI-4-All scientists performing the same procedures may not get the same results<br>SI-7- Scientific data are not the same as evidence<br>SI-8-Explanations are developed from a combination of collected data and what is already known |

**Appendix 2.** VASI Evaluation Rubric Created from Study Group Student Responses

| Aspect of Scientific Inquiry | Naïve | Mixed | Informed |
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| **1. Scientific investigations all begin with a question and do not necessarily test a hypothesis (SI 1)** | *1a:* "Yes, it is scientific. Because investigating and experimenting birds' beaks shape and what they eat are scientific." *1b:* "I think it is an experiment. Because it's about birds, they make an investigation, they examine it, so they make an experiment." *2:* "No, I do not think so. Because it can be asked with another question." | *1a:* "It is a scientific investigation. They were observing animals. In science classes living beings are observed." *1b:* "It is not a scientific investigation; it is not an experiment." *2:* "It should start with a question. No reason." | *1a:* "I think it's scientific investigation. As a result, he collected data, conducted research, and reached a conclusion as a result. So, a scientific explanation" *1b:* "I don't think it's an experiment. I don't think you can reach a definite result in the experiment. Something has to change...But not here. In other words, you can collect data in scientific research, and we can reach the result." *2:* "Yes. As a result, scientific research is done by asking a question and following it. When we ask a question, we wonder about it, and we do research." |
| **2. There is no single set or sequence of steps followed in all investigations (SI 2)** | *1b:* "No, it is not an experiment. Because in experiments you mix something with liquids, etc." *1c:* "Some observe, some take photographs..." | *1b:* "No it is not an experiment. They do not experiment on something or mix some liquids. They investigate one bird's beak; this does not have the features of experiments." *1c:* "There are multiple ways. For example, some people can do something with different ways." | *1b:* "Teacher, I do not think it is an experiment, they have a conclusion based on their observation." *1c:* "Scientific investigation can be done with more than one only way" |
| **3. Inquiry procedures are guided by the question asked (SI 3)** | "Group A. Because they look at each one by one. / Group A because they both thought that these tires are flat" | "I would agree on research group B. because we cannot move on one type of surface. But Group B they tried 3 different ways." | "It would be more logical if they mixed both methods. On 3 three different ways/surfaces with 3 different brands." |

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| **4. All scientists performing the same procedures may not get the same results (SI 4)** | "They think differently. I think it would be the same. It would be different if it was different research. If it was a same research, same kind of research, it would be the same." | "No, some people may have a different opinion. They may have thought differently. Therefore, their experiments are different." | "Teacher for example, they will research something, but the way of research is the same, but when adding their own thoughts, those ideas, that way may change." |
| **5. Inquiry procedures can influence results (SI 5)** | " Same results, same thoughts, processes" | "No, because they follow different processes" / "I think it's different. For example, one scientist tries to solve it without looking at anything, the other gets help from books and encyclopedias. It would be different" | "No, because when different processes are followed, everyone's opinion is different for different processes. They do not achieve the same results. Because all people have different opinions. And in some processes, people's opinions can change. When they do it at different times, they get different results." |
| **6. Research conclusions must be consistent with the data collected (SI 6)** | "Option A. Plants grow in sunlight " | "I think it is Option B. Plants grow more when they receive less sunlight. Because when it receives light for 0 minutes, it grows 25 cm. It was the longest at that time." | "Option B. Because as the light duration decreases in the chart, the plant grows longer." / " Option C. Looking at the graph above, we see that, on average, there is no need for light, that is, little light is needed." |
| **7. Scientific data are not the same as scientific evidence (SI 7)** | "No, data and evidence are not different. Data is a resource; evidence is a resource." | "Data and evidence are different. Data is information that people collect about a topic. Evidence is the remaining clues, i.e., evidence, to find the criminal at a crime scene. It may be close, but evidence is to prove something, like data to determine its answer." | "I think data and evidence are different. Data is the information we have about a subject. Evidence is information to prove an event. That's why I think it's different. Data is the information we have to investigate a subject. Evidence is what we have to prove a subject. information." |

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| **8. Explanations are developed from a combination of collected data and what is already known (SI 8)** | *7a:* "Because they found the fossils of the other while walking. Because, according to Fig.2, they cannot walk like that."<br>*7b:* " They have done their own research." | *7a:* " I think that's right here, but such thin legs cannot support this torso."<br>*7b:* "From past information. For example, the earth is round. They understood by their own efforts, for example, by sending astronauts. They take pictures and see that it is round." | *7a:* " Because the fossils of dinosaurs' footprints are large. Teacher, paleontologists find the footprints of dinosaurs and stuff. In the footprints, they may not fit because the dinosaurs' forehands are smaller, and the footprints are larger. I think that's why they do it. There is also a point where each bone fits together. I think that's where scientists step in and test which bone fits which bone. Their large feet allow them to run fast. If they didn't have big feet, they wouldn't be able to run fast. They reach for large trees for food. Therefore, they must be tall. Because they run fast. Because two feet are visible in the tracks."<br>*7b:* "Footprints, fossils, bone information, features, living conditions. They find footprints, fossils, etc. Scientists also experiment with them. For example, they take the human body as an example. After all, the bones of every human being are similar to each other, and they take samples from the bones of creatures similar to other dinosaurs and try each other first and place them. They are also doing something, my teacher, for example, they are trying to do it in accordance with the way of life of that time." |