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CONCEPTUAL DEVELOPMENT OF 7TH GRADE STUDENTS PROVIDED INQUIRY BASED GEOSCIENCE EDUCATION

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Abstract. *Learning about the Earth through geoscience education is important in order to make informed decisions about the future of the Earth. The aim of this study is to examine students' conceptual development on geoscience subjects based on inquiry-based learning. 7th grade students participated in this study. The researcher prepared lesson plans and activities connected with the aforementioned subjects in accordance with the inquiry-based learning model. In this study, the "Geoscience Concept Achievement Test (GCAT)" was used in order to obtain quantitative data, and it was applied as a pre-post test and also a retention test. Qualitative data obtained from 8 students, selected from the working group using the maximum sampling method, Science Writing Heuristics (SWH), interviews with the students, worksheets and assessment tests were used as qualitative data collection tools. The geoscience education program was implemented for 8 weeks. The results from quantitative and qualitative data showed that geoscience education positively affected 7th grade students' conceptual understanding of geoscience subjects. The results of the students' GCAT pre-test, post-test, retention test, SWH data, weekly interviews with the students and final interviews, revealed that the learning and teaching process applied in geoscience education positively affected their conceptual development regarding the subject of geoscience.*

Keywords: *conceptual development, geoscience education, inquiry based education, mixed methods research*

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Introduction

Over millions of years, the Earth has undergone profound geological transformations shaped by tectonic shifts, climatic variations, and natural phenomena. Throughout history, the evolution of humanity has been intimately linked with the advancement of geoscience and education. Furthermore, geoscience is a branch of research that works with time scales, looks at the progressive changes that occur in both organic and inorganic structures in nature, and goes far beyond human experience (Mayer & Armstrong, 1990). As a subfield of earth sciences, geoscience makes predictions about the future based on data from the planet's past and present, as well as historical events using data from the present (King, 2014; Lee & Fortner, 2005). It draws on concepts from biology, chemistry, physics, mathematics, geography, and engineering to make these predictions.

Interdisciplinary, practical, inquiry-based scientific activities should be conducted and curriculum goals ought to be achieved in order for students to acquire geological concepts more permanently and meaningfully (American Geological Institute, 2006; Ault, 1982; Blake, 2004). Many geological processes are difficult for students to understand, which prevents them from grasping the characteristics and structure of the Earth (Johnson, 2006; Smith & Siegel, 2004). Hawley (2002) has emphasized that the majority of individuals lack sufficient understanding of the theoretical framework of the global system. In light of this, science educators should develop curricula that help students understand the fundamentals of soil and rock formations. The field of geoscience attracts numerous people who enjoy asking questions and finding answers or collecting fascinating information about Earth's dynamic systems. However, other people pursue careers in geology, spending their lives asking and finding answers to earth science questions (Boatright et al., 2020). Geologists explore for new Earth resources by traveling to all parts of the world, from the tropics to the poles, the highest mountains to the deepest seas. Even though we might have grown up with a collection of rocks or a dinosaur obsession, early exposure to geology in the classroom is frequently limited. Geoscience needs to be emphasized more in educational programs if we want to inspire the next generation of geologists. At times, geoscience is randomly included in other courses such as physics, chemistry, or geography. In summary, due to a lack of understanding, most science teachers find it difficult to teach subjects in the field of geosciences (Boatright et al., 2020; King, 2021; Locke et al., 2012).

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The National Research Council (1996) recommended materials for teaching appropriate geoscience topics in primary, lower-secondary, and upper-secondary schools that include the structure and development of the earth. It is crucial to educate students at this level even if it may be challenging to teach them abstract concepts like the beginning and structure of the earth and solar system. This ensures that when they graduate from high school, they have a comprehensive understanding of geoscience concepts. When studying geoscience, some people find it difficult to understand natural cycles, time scales, and the continual change of subsystems (Kortz & Murray, 2009). The understanding of the Earth's structure, the capacity to conduct experiments, and the ability to determine geological concepts provide the basis for teaching primary school students about Earth's structure (Griffin, 2016).

The fundamental science learning outcomes in the science curriculum of the Ministry of National Education of the Republic of Turkey and the science curricula of countries (South Korea, Finland, Estonia, United Kingdom, United States of America) that have a high success rate in international exams (PISA, TIMSS, etc.) are used as a basis when developing activity and lesson plans for the geosciences topics included in the study.

Theoretical Background

Research on Why People Need to Learn Geoscience

Spatial reasoning and keen observation are essential for comprehending the world's structure, changes over time, and subsystems (Kastens & Rivet, 2008; Orion & Ault, 2007). Students can gain a better understanding of geochemical and geophysical processes as well as the structure and history of the planet by using effective observation techniques (Ault, 1998; Ford, 2005).

Studying geology develops higher-level thinking skills. Identifying, describing, and categorizing an object's shape, explaining its location and orientation, developing and using maps, and three-dimensional thinking are all examples of spatial thinking techniques. Geoscience helps to develop people's mental and scientific processes since it is associated with large-scale, three-dimensional spatial thinking (Kastens & Ishikawa, 2006). Spatial skills are often developed, evaluated, and rewarded in the formal schooling system. However, current research argues that both instruction and practice can enhance geoscience activities that foster applied and abstract spatial thinking (Kastens & Ishikawa, 2006; Kastens et al., 2009).

Teaching geology to students can give them a useful instrument for interacting with society concerns (LaDue & Clark, 2012). Geoscience literate people may be better equipped to solve problems and make decisions when it comes to solving social issues like resource scarcity, climate change, and sustainability.

Limitations of Existing Research and Justification of the Study

The literature review indicates that the subject mostly focuses on teaching earth science at the undergraduate and graduate levels, with a particular emphasis on the study of geological time (Cheek, 2011; Clary et al., 2009; Czajka & McConnel, 2018; Teed & Slattery, 2011). LaDue and Clark (2012) conducted surveys with geoscience educators attending a geological convention to investigate the challenges and issues regarding geoscience education. The participants cited a lack of respect for earth sciences and the deficiencies of geoscience education in primary, lower-secondary, and upper-secondary schools as major obstacles to geoscience education. In order to collect data on how geoscience education is presented at the school level worldwide, UNESCO and the International Geosciences Organization (IGEO) surveyed specialists from 51 countries, which account for more than half of the world's population (King et al., 2021). The IGEO website has all the data (IGEO, 2014). The results of this survey revealed that most children were required to take a geoscience curriculum, with 75% of the countries examined having such a curriculum. However based on the research, more than half of the nations examined do not adhere to geoscience accepted standards. According to IGEO (2014), just 25% of nations include geoscience-related subjects in their standardized entrance exams.

It has been discovered that studies at the primary and secondary levels mainly examine curriculum and perspectives presented in international projects (Fermeli et al., 2011; Iverson et al., 2019; Marques et al., 2003). According to research, geoscience education is crucial, and it should be incorporated into science literacy programs and taught to children through hands-on learning beginning at a young age (Mayer & Armstrong, 1990; Reis et al., 2014; Uçar, 2009). In the first stage of the current study, the subjects and achievements of the Ministry of Education's Science curriculum were examined. Following that, activity-based lesson plans based on the inquiry-based teach-

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ing paradigm were developed for the achievements that are and are not included in Turkey's science curriculum related to geoscience subjects. These plans were inspired by the science curriculum of the PISA highest-scoring countries. In accordance with the inquiry-based method of instruction identified in the literature, these lesson plans aim to make a contribution to the field by addressing a need in geoscience education.

According to researchers, curriculum development and renewal efforts often focus on specific concepts and processes and fail to connect these concepts to the world system in which they interact (Mayer & Armstrong, 1990; Locke et al. , 2012; King et al., 2021). At the same time, it is stated that the science curriculum is confined to a centuries-old curriculum consisting of biology, chemistry and physics and is inadequate in geoscience education (King et al., 1995; Lee & Fortner, 2005). Although the importance of geoscience education in science education is evident in international exams (PISA, TIMSS, etc.), geoscience education is carried out through international projects and intermediaries such as the European Geoscience Union (EGU), International Geological Education Association (IGEO), National Science Education Standards (NRC). A worldwide call is being made about the necessity of education. Lesson plans for basic geoscience subjects have been tried to be developed in accordance with the inquiry-based teaching model using innovative teaching approaches. Individuals trained in geoscience can provide support in securing essential living resources and protecting and enhancing natural processes that can help improve the living standards of local communities. In this context, teaching programs in geoscience courses can be developed in the education of individuals who can understand the impact of human activities on the Earth and have high awareness of the impact of Earth processes on humans.

Research Aim and Research Questions

Lesson plans developed by the researcher and an inquiry-based teaching methodology for geoscience courses were employed in the study. Because geoscience education involves active learning and requires the application of higher order thinking skills, it is taught using an inquiry-based approach. Students are encouraged to think critically about real-world problems and attempt to solve them using the newly acquired information and abilities (Biological Science Curriculum Study, 2006; Delen & Uzun, 2018; Duran, 2015). Furthermore, inquiry-based approach geoscience lesson plans and activities, developed in accordance with the inquiry-based method utilized in Turkey's science curriculum, aim to provide teachers and students with the required infrastructure.

In this study, inquiry-based geoscience education implemented for a study group consisting of 7th grade students was examined using quantitative and qualitative data collection methods. The research questions were the following:

1. What are the conceptual understandings of 7th grade students about basic geoscience subjects at the end of the geoscience education program?
2. What are the opinions and judgments of 7th grade students regarding the educational process?
3. Are the qualitative data obtained from the research compatible with the quantitative data?

Research Methodology

General Background

The research focused on examining students' conceptual development in geoscience subjects based on inquiry-based learning. It was predicted that inquiry-based learning activities enhanced 7th grade students'conceptual development on geoscience subjects. Therefore, geoscience education training was implemented for 8 weeks in the second semester of the 2022-2023 academic year. Quantitative and qualitative data were collected for this purpose. The methodology of the research was planned as an embedded research design in order to capture the current situation of the conceptual development of geoscience subjects and to answer the question of how students' conceptual understanding of geoscience has changed.

In order to contribute to the science education program, geoscience lesson plans were prepared in accordance with the inquiry-based teaching model, and 7th grade students' conceptual developments were examined by applying them. The reason for including 7th grade students in the study group is that their readiness level is appropriate in terms of learning some abstract topics (plate tectonics, geological time) among the subjects of geoscience education.

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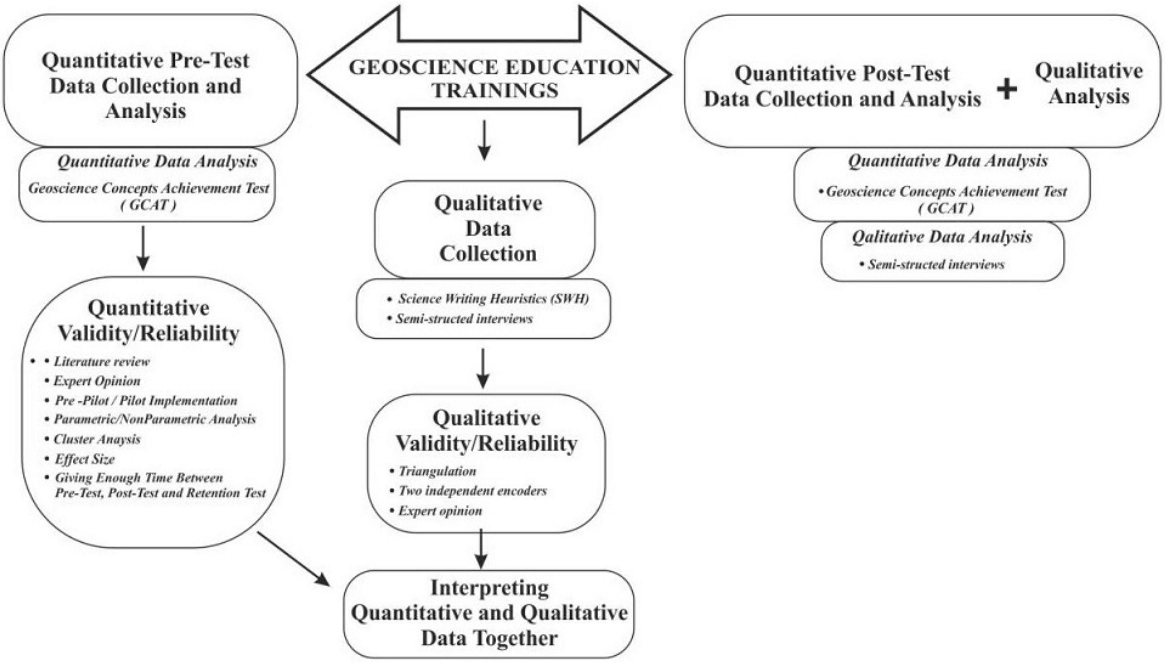
Design

As a means to examine the research questions, a mixed methods strategy was employed in this study (Creswell & Plano Clark, 2018; Toraman, 2021). Since it allowed the exploration of multiple facets of an event by combining various data types, mixed method research was frequently chosen in the field of education (Bryman, 2001; Silvermen, 2000).

One of the mixed methods research designs utilized in this study was "embedded design" (Creswell & Plano Clark, 2018). To promote the development of the overall design, the researcher can incorporate a qualitative phase into a quantitative study or a quantitative phase into a qualitative study in this design (Toraman, 2021). Students in the seventh grade received geoscience teaching in this study, and their conceptual grasp of foundational geoscience topics was assessed. Quantitative data gathering techniques were incorporated into the case study's basic design, or primary design (Figure 1). GCAT was employed as a quantitative data collection method to examine how seventh-grade students' conceptual grasp of geoscience subjects was affected. In order to assess the 7th grade students' prior knowledge and the impact of the application, GCAT was incorporated into the case study both before and after the application. Attempts were made to increase data diversity(observation, interview, field notes, science notebook) to the greatest extent possible during the qualitative data collection process. Through the use of both qualitative and quantitative data collection methods, the opinions of seventh grade students on geoscience education were assessed. By considering the results of the research from a wider viewpoint, the use of various data types aims to enhance the database (Çepni, 2014). The purpose of gathering data for the study, both quantitative and qualitative, is to integrate various data formats by acquiring information from each data type independently to enhance comprehension of the issue. The research design is given in Figure 1:

Figure 1
Research Design



Participants

In this study, quantitative and qualitative data were collected from 7th grade students at a public school in Hatay in order to examine students' conceptual understanding of geoscience subjects. Since the students in this public school come from different regions, it can be said that the group has a heterogeneous structure. Two study groups were formed for this research (Table 1). It might be argued that the group has a heterogeneous structure because the students of this public school come from a variety of geographic areas. Two study groups took part in the study (Table 1).

Table 1
Characteristics of the Sample and Study Group

Gender	Sample	Study group
Female	17	5
Male	14	3
Total	31	8

The primary group, which consists of 31 students, used quantitative data collection instruments in a group setting and conducted pre-tests and post-tests. Within the primary group, a second group was chosen. The study group was established during the qualitative phase, which is the fundamental research design, by carefully choosing members of the sample that was utilized in the quantitative procedure. In this procedure, maximum variation sampling—which is frequently used in the qualitative portion of the embedded design—was employed. Based on the results of the pre-test, the students were classified into three groups: those with poor conceptual understanding, those with medium conceptual understanding, and those with high conceptual comprehension. Students' varied points of view, therefore, offer a useful qualitative procedure that captures these variations and seeks to address the research topic (Cresswell & Plano Clark, 2011). The study group collected doesn't allow for the generalisation of research results. In fact, as mixed methods research, it aims to conduct an in-depth examination as a case study rather than a generalization.

In the process of determining the study group within the scope of the research, information about the content and process of the research was given to the 7th grade students and the research process was started with those who were willing. In addition, a certificate of approval was obtained from the ethics committee of Mersin University.

Instrument and Procedures

The relationship between the research questions and data collection tools is shown in Table 2.

Table 2
Research Questions and Data Collection Tools Used

Research questions	Data collection tools
1. What are the conceptual understandings of 7th grade students about basic geoscience subjects at the end of the geoscience education program?	Science Writing Heuristics (SWH), Semi-structured interviews, Worksheets and assessment test
2. What are the opinions and judgments of 7th grade students regarding the educational process?	Semi-structured interviews
3. Are the qualitative data obtained from the research compatible with the quantitative data?	GCAT, SWH and qualitative data

Geoscience Concept Achievement Test (GCAT)

Learning outcomes in science curriculum in Turkey and a few PISA high-scoring countries (South Korea, United Kingdom, Finland, Estonia, United States (Colombia)) were examined in order to create GCAT questions (Keskin Çevik et al., 2021). The science curriculum of these nations has been used to create a table of standards for the GCAT, which will help shape the pool of questions. A preliminary pilot study was conducted following the selection of test items from the question pool and expert consultation. The analyses led to the creation of the GCAT, which has 21 questions covering the fundamental geoscience subjects.

Two weeks prior to the start of the geoscience education program, the GCAT was administered as a pre-test, and afterwards as a post-test. There is a ten-week interval between each application. Eighteen weeks following the completion of all applications, the permanence test was conducted.

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Science Writing Heuristic (SWH)

Keys et al. (1999) described the Science Writing Heuristic as a tool that helps students comprehend scientific topics and organize their knowledge. There is a SWH template in Table 3.

Table 3
SWH Student Template (Keys et al., 1999)

Initial thoughts------------> My questions?
Testing ------------> What I did?
Observation ------------> What I saw/observed?
Claims ------------> What can I claim?
Evidence ------------> Why am I making these claims?
Thoughts ------------> How can my thoughts compare with others?
Changes ------------> Have my thoughts changed?/How have they changed?

SWH was used to help students organize the knowledge they learned through writing and to help them adjust to the inquiry-based learning process. Students used colored pencils and A4 paper to construct their own SWH prior to application. Before the application, the researcher discussed with the students about what kinds of notes they might take in the SWH, and they provided the necessary explanations by using the items in the SWH template. Students were informed that they could only complete their science writing heuristics during the course session and that the notebooks would be collected at the end of each course throughout the eight-week application period. The researcher also emphasized that in addition to the parts in the SWH template, students could draw explanations of geoscience subjects. The students received no teaching while they were using the SWH; they were left to their own devices. The best SWH chosen at the end of the educational process would receive a reward, and the students were informed.

Semi-structured Interviews

The semi-structured interview form included open-ended questions that aimed to get an in-depth understanding of the students' perspectives on the study group's educational process while also clarifying and supporting the GCAT. The questions in the interviews changed according to the geoscience topics in the weekly programs in geoscience education. Semi-structured interview questions include questions such as students' opinions about geoscience activities, the impact of geoscience subjects on their future learning, whether they want to be a geologist in the future. After 8 weeks of geoscience education, students were asked 10 open-ended questions about the process. Some of these questions are:

> *"What were the activities that you enjoyed doing the most in the process, why?",*
> *"Which activities in this process do you think were most effective in your understanding of the subject?",*
> *"Do you think that geoscience education will have an impact on your future learning?"* …

The literature was reviewed and the relevant resources were examined in order to ensure content validity when developing the interview form (Ketin, 2005; King et al., 2021; Wysession et al., 2010). Three academicians who are specialists in the field provided their opinions to help prepare the draft form.

Following the geoscience education course, at least two study participants took part in a pilot application of the semi-structured interview form. Probe-type questions were added to the finalized interview form through the process of making sure it would be used when needed, depending on the circumstances of the participants (e.g., difficulty in understanding and misinterpreting the questions). After examining the analysis of quantitative data, the finalized semi-structured interview form was administered to students with low, medium, and high achievement levels in the process. Confidentiality and ethical guidelines were prioritized during the study (Fraenkel & Wallen, 2006).

Worksheets and Evaluation Questions

Explanatory texts, such as worksheets and assessment tests created in line with the lesson's subject matter, were used as crucial data sources following every lesson as a means to find the views and thoughts of the students. The assessment questions also include open-ended questions in addition to the typical True/False and multiple choice question formats. Two specialists in science and geosciences reviewed the worksheets and assessment questions that the researcher had created. The revision was made in accordance with the suggestions given by the experts.

Data Collection Process

The study employed the Skilbeck (1984) program development model. The philosophy of classical humanism has an impact on this program development paradigm. Given that it is grounded on the idea of school-centered program development, it places a high value on the assessment of the conditions within the school and its immediate environs. The following is the flowchart used in the creation of creative and situational programs:

Situation analysis: It has been determined that there are deficiencies in the program regarding geoscience education. The secondary school science curriculum in our country was examined in regard to geoscience education. In addition, the science curricula of the countries that achieved outstanding results in international exams were also examined and a table of specifications and a concept map for geoscience education were created.

Purposes: The aims of the program regarding geoscience education were determined after examining national and international curricula. Lesson plans for geoscience education were prepared and the geoscience achievements in the examined curricula were associated with sustainable environmental awareness achievements. Expert opinions were received regarding the suitability of the prepared lesson plans.

Learning-teaching: Geoscience lesson plans include activities fitting the inquiry-based teaching model.

Patterning program: Innovative learning approaches (out of school/classroom learning, project-based learning, STEM, etc.) were used in designing the lesson plans after reviewing the literature during the geoscience education design process. The program includes basic geoscience subjects (Earth's structure and formation, Earth's layers, minerals and rocks, soil structure and types, fossils, plate tectonics, geological time, destructive natural events).

Applying the program: Geoscience education, covering basic geoscience topics, was implemented to the working group for 8 weeks. Quantitative and qualitative data collection tools were used throughout the program.

Evaluation: The findings obtained from quantitative and qualitative data collection tools were analyzed, the results were interpreted and suggestions were made regarding the geoscience education process.

Data Analysis

To calculate the internal consistency in the study, the KR-20 formula was used since the test items were scored as 1 (true) and 0 (incorrect) (Büyüköztürk, 2007). GCAT KR-20 analysis findings are as shown in Table 4.

Table 4
GCAT KR-20 Analysis Findings

N	*X*	*SD*	*Md*	*Mo*	*p*	*KR-20*
144	13.778	4.083	14	16	0.556	0.810

The KR-20 score of this test was calculated as .810 (Table 4). The fact that the calculated value is greater than .70 indicates that the developed test has internal consistency and is reliable (Şencan, 2005).

SWH were examined in depth and correlated with the data obtained from the interviews. SWH used by the students during the activities were evaluated to see if they included the target concepts previously determined by the researcher. SWH of the interviewed students were examined weekly during the application process. Data from students who made drawings about target concepts in their SWH were also analyzed.

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In order to evaluate the participants' answers to the worksheet and evaluation questions, each answer was subjected to content analysis and explained under the determined themes. Each activity was evaluated separately, categories were created from common experiences, and average and percentage (%) values were calculated. Content analysis and descriptive analysis were used to analyze other qualitative data in the study.

Joint Display Analysis

Although mixed methods research has become an important research method in many disciplines, the integration of quantitative and qualitative data remains deficient (Guetterman et al., 2015). It is emphasized in the studies that data correlation is not made in mixed methods research or is limited to statistical side-by-side comparisons according to themes (Fetters, 2020; Fetters et al., 2015).

The shortcomings of both quantitative and qualitative research are countered by visualization through data correlation in mixed methods research (Creswell & Plano Clark, 2018; Johnson et al., 2017). Associating simultaneous qualitative and quantitative data allows for the visualization of the cognitive processes involved in the planning and execution of the study (Fetters, 2020).

The quantitative and qualitative data utilized in the analysis of mixed methods research were visualized in the study using joint display. Together with statistical analyses from the GCAT's pre-, post- and retention tests, data on target concepts from the SWH during the application process, and qualitative information from weekly and final interviews, a joint display analysis was created to assess students' conceptual understanding of geoscience.

Research Results

Conceptual Understandings of 7th Grade Students about Basic Geoscience Subjects

The SWH and worksheet of the students were used to determine the conceptual understanding of 7th grade students on basic geoscience topics following the geoscience education program.

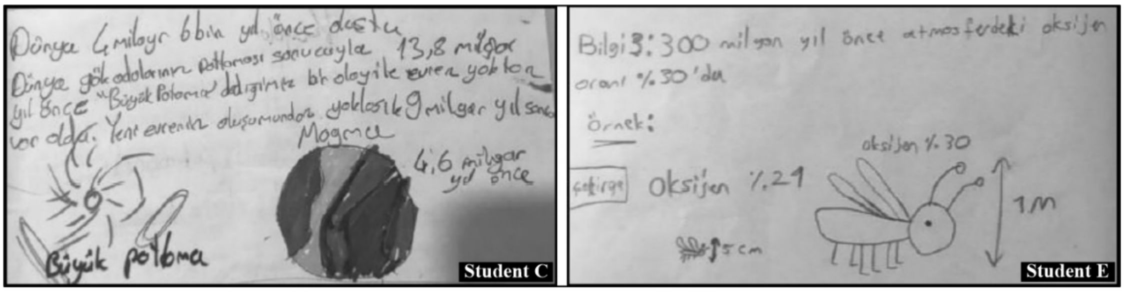
The target concepts for the first basic geoscience topic in the implementation process (the structure and formation of the Earth) and the review of the working group's science notebooks (SWH) and worksheets are given in Table 5.

Table 5
The Target Concepts for the First Basic Geoscience Topic and the Review of the Working Group's SWH and Worksheets

Geoscience subject	Target theme		Student							
			A	B	C	D	E	F	G	H
Structure and formation of the Earth	*Concepts of hypothesis*	Big bang	✓				✓	✓	✓	
		Magma	✓				✓		✓	
	Drawing				✓				✓	
	Concepts regarding changes in the world	Changes in the Earth and human impacts	✓				✓	✓	✓	✓
		Past Earth-Present Earth relationship	✓		✓	✓	✓	✓		
		Past views on the formation of the Earth			✓	✓	✓	✓		
		Predictions for future changes			✓		✓			✓
	Drawing				✓	✓				
	Concepts of time-related	Age of Earth	✓	✓	✓	✓	✓	✓	✓	✓
		Age of Universe	✓	✓		✓	✓	✓	✓	
	Drawing				✓		✓		✓	
Number of true answers			7	6	8	7	8	7	7	6

After examining the SWH and worksheets collected during the first week, it was seen that two students (C and E) answered all the questions correctly in the post-application worksheet. When the SWH of students C and E were examined, it was revealed that Student C made the highest number of drawings regarding the sub-concepts of the subject, and Student E took the highest number of notes on the subject. Two of the drawings made by the students (C and E) in their science notebooks regarding the structure and formation of the Earth are shown in Figure 2.

Figure 2
SWH Drawings of Student C and Student E Made During the First Week



The target concepts for the second basic geoscience topic in the implementation process (Layers of the Earth) and the review of the working group's science notebooks (SWH) and worksheets are given in Table 6.

Table 6
The Target Concepts for the Second Basic Geoscience Topic and the Review of the Working Group's SWH and Worksheets

Geoscience subject	Target theme	Student							
		A	B	C	D	E	F	G	H
Layers of the Earth	Concepts for the names of Earth layers (Barysphere, magma, hydrosphere, lithosphere, atmosphere)	✓	✓	✓	✓	✓	✓	✓	✓
	Drawing	✓	✓	✓	✓	✓	✓	✓	✓
	Concepts regarding the states of matter in layers (Solid, liquid, gas)	✓	✓	✓	✓	✓	✓	✓	
	Drawing	✓	✓	✓		✓	✓	✓	
	Number of true answers	8	8	8	8	8	8	8	7

When Table 6 was examined, it was concluded that all students except one, answered all the questions regarding the layers of the Earth correctly. This may be caused by the fact that students have prior knowledge about this subject and that their achievements regarding the subject are included in the curriculum. The target concepts for the third basic geoscience topic in the implementation process (Minerals and rocks) and the review of the working group's SWH, worksheets are given in Table 7.

Table 7
The Target Concepts for the Third Basic Geoscience Topic and the Review of the Working Group's SWH and Worksheets

Geoscience subject	Target theme		Student							
			A	B	C	D	E	F	G	H
Minerals and rocks	Concepts regarding rock types	Igneous rocks-sedimentary rocks	✓	✓	✓	✓	✓	✓	✓	✓
		Intrusive rocks- extrusive rocks		✓		✓			✓	
		Metamorphosis (metamorphic) rocks	✓	✓		✓	✓	✓	✓	✓
	Drawing		✓		✓		✓	✓	✓	✓
	Concepts for rock samples	Obsidian, basalt		✓	✓	✓	✓		✓	
		Tuff (Fairy chimneys), chalk	✓	✓			✓	✓	✓	
		Sandstone, clay stone		✓	✓				✓	
		Diamond, limestone	✓				✓		✓	
		Quartz, coal, marble		✓						
	Drawing				✓			✓		
	Concepts regarding rock formation	Magma	✓			✓	✓		✓	✓
		Pressure, temperature	✓	✓				✓		
		Rock cycle		✓				✓	✓	
		Time						✓		
		Earth crust					✓			
	Drawing						✓			
	Concepts for determining the type of rock	Mineral		✓		✓	✓	✓	✓	
		Petrography	✓	✓		✓		✓	✓	
		Fossil			✓		✓		✓	
	Drawing		✓	✓			✓		✓	
	Number of true answers		7	8	7	7	8	7	8	6

After examining the SWH and worksheets collected during the third week, it was seen that three students (B, E, G) answered all the questions correctly in the post-application worksheet. When the SWH of these students are examined, it is seen that they mostly take notes and draw the target concepts for the subject. Two of the drawings made by the students (B and G) in their SWH on the minerals and rocks are shown in Figure 3.

Figure 3
SWH Drawings of Student B and Student G Made During the Third Week

The target concepts for the fourth basic geoscience topic in the implementation process (Structure and Types of soil) and the review of the working group's SWH and worksheets are given in Table 8.

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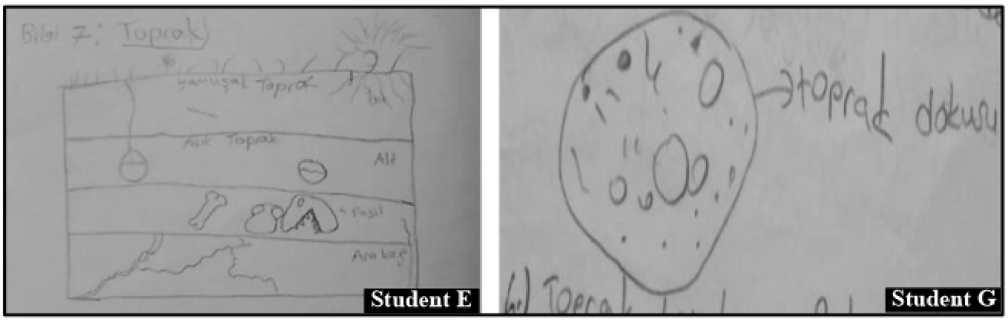
Table 8
The Target Concepts for the Fourth Basic Geoscience Topic

Geoscience subject		Target theme	Student							
			A	B	C	D	E	F	G	H
Structure and Types of Soil	Concepts for soil types	Sandy soil, marl	✓	✓	✓	✓	✓	✓	✓	✓
		Clayey soil	✓	✓		✓	✓	✓	✓	✓
		Humus soil	✓	✓		✓	✓		✓	✓
	Concepts for soil layers	Soil horizon	✓			✓	✓		✓	✓
		Top layer, bottom layer, bedrock	✓	✓			✓		✓	
		Age of fossils		✓		✓	✓		✓	
	Drawing				✓	✓		✓		
	Concepts regarding the content of the soil	Soil texture	✓			✓	✓		✓	✓
		Sand, clay, silt	✓	✓					✓	
		Rock, coal						✓		
		Weather	✓	✓		✓	✓			
		Animals (insect, worm…)	✓	✓	✓		✓			
		Organic and inorganic compounds	✓	✓			✓			
	Drawing						✓		✓	
	Concepts for determining soil type	Water holding capacity	✓	✓		✓	✓	✓	✓	
		Permeability	✓	✓	✓	✓		✓	✓	
		Colour	✓		✓		✓	✓	✓	
		Agricultural suitability			✓		✓		✓	
	Drawing								✓	
	Number of true answers		7	7	7	7	8	7	8	6

When Table 8 was examined, it was seen that the students who took notes and made drawings of the target concepts in their SWH had a higher number of correct answers on the worksheet applied at the end of the course. Two of the drawings made by the students (E and G) in their SWH regarding the structure and types of soil are shown in Figure 4.

Figure 4
SWH Drawings of Student E and Student G Made During the Fourth Week



The target concepts for the fifth basic geoscience topic in the implementation process (Fossils) and the review of the working group's SWH and worksheets are given in Table 9.

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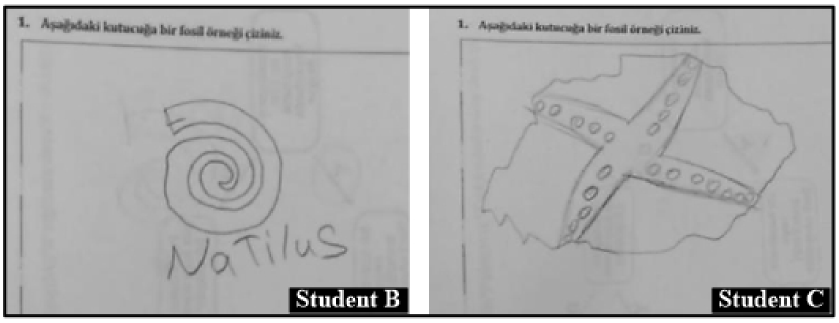
Table 9
The Target Concepts for the Fifth Basic Geoscience Topic

Geoscience subject	Target theme		Student							
			A	B	C	D	E	F	G	H
Fossils	Concepts regarding fossil formation	Million years	✓	✓	✓	✓	✓			✓
		Calcification	✓			✓				
		Precipitation	✓		✓					
		Living remains	✓	✓			✓			
		Sedimentary rock				✓		✓		
		Fossilization	✓		✓	✓				✓
	Drawing									
	Concepts for fossil types	Trace fossil (tooth, bone...)		✓		✓		✓		
		Body fossil (amber..)	✓	✓			✓	✓		
		Chemofossil (biological waste...)		✓				✓		
	Drawing			✓	✓					
	Concepts related to fossil science	Paleontology	✓	✓		✓	✓	✓	✓	
		Archaeology, Geology				✓	✓			
	Drawing									
	Number of true answers		8	8	8	8	8	8	7	7

After examining the SWH and worksheets collected during the fifth week, it was seen that six students answered all the questions correctly on the post-application worksheet. It was concluded that all the students, except two, answered all the questions regarding fossils correctly. This may be caused by the fact that the students had prior knowledge about this subject and that the achievements regarding the subject are included in the curriculum. When the SWH of the students who answered all the questions correctly are examined, it is seen that they mostly take notes and draw the target concepts for the subject. Two of the drawings made by the students (B and C) in their SWH regarding fossils are shown in Figure 5.

Figure 5
SWH Drawings of Student B and Student C Made During the Fifth Week



The target concepts for the sixth basic geoscience topic in the implementation process (Plate tectonics) and the review of the working group's SWH and worksheets are given in Table 10.

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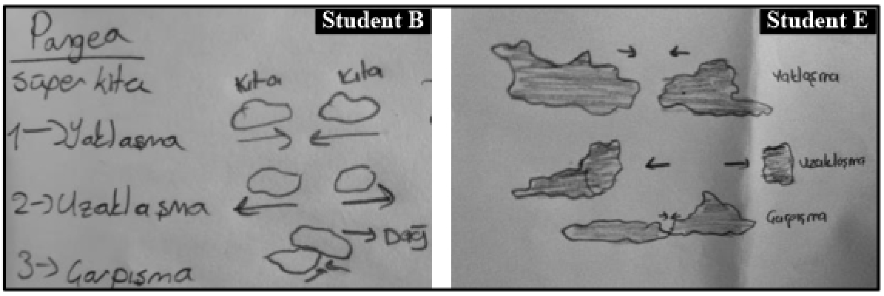
Table 10
The Target Concepts for the Sixth Basic Geoscience Topic

Geoscience subject	Target theme		Student							
			A	B	C	D	E	F	G	H
Plate tectonics	Concepts regarding the factors that cause plate tectonics	Earth crust		✓	✓	✓				
		Magma			✓	✓			✓	
		Earth's rotation speed		✓			✓			
	Drawing									
	Concepts regarding types of plate movements	Approaching, moving away		✓		✓	✓	✓	✓	✓
		Collision	✓			✓	✓	✓	✓	✓
	Drawing			✓			✓			
	Concepts regarding the formation of plate tectonics	Pangea (supercontinent)	✓	✓	✓		✓	✓	✓	
		Island, continent, mountain	✓	✓			✓	✓	✓	
		Earthquake, volcanic eruption		✓	✓		✓		✓	
		Geothermal resources		✓						
	Drawing									
Number of true answers			6	8	7	7	8	7	7	6

When Table 10 was examined, it was seen that the students who took notes and made drawings of the target concepts in their SWH had a higher number of correct answers on the worksheet applied at the end of the course. Two of the drawings made by the students (B and E) in their SWH on the plate tectonics are shown in Figure 6.

Figure 6
SWH Drawings of Student B and Student E Made During the Sixth Week



The target concepts for the seventh basic geoscience topic in the implementation process (Geological time) and the review of the working group's SWH and worksheets are given in Table 11.

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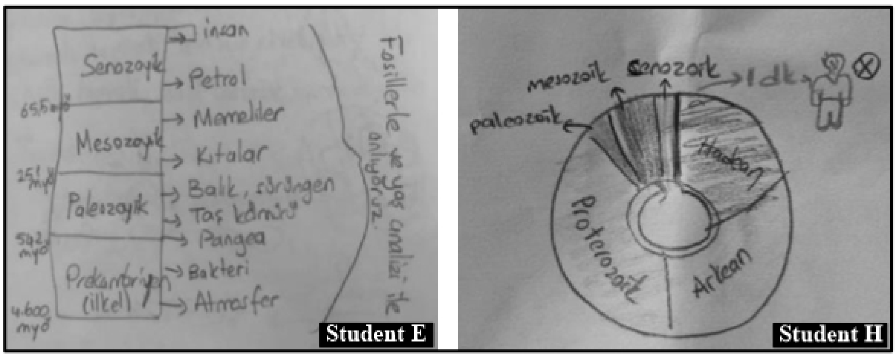
Table 11
The Target Concepts for the Seventh Basic Geoscience Topic

Geoscience subject	Target theme		Student							
			A	B	C	D	E	F	G	H
Geological time	Concepts regarding basic geological times (Precambrian, Paleozoic, Mesozoic, Cenozoic)		✓	✓	✓	✓	✓	✓	✓	✓
	Drawing						✓			✓
	Concepts regarding important events in geological time	Formation of the atmosphere and Pangea	✓	✓			✓		✓	✓
		Formation of coal	✓	✓			✓			
		Separation of continents, formation of mountains and oceans						✓		✓
		Emergence of microscopic creatures	✓	✓			✓	✓		
		Emergence of advanced organisms					✓	✓		✓
		Extinction of dinosaurs and large plants		✓			✓	✓		
		Formation of oil, lignite and salt deposits					✓			✓
	Drawing									
	Number of true answers		5	4	4	3	8	6	5	7

After examining the SWH and worksheets collected during the seventh week, it was seen that only student E answered all the questions correctly on the post-application worksheet. When the worksheets of the students were examined, it was seen that the ones who had a higher number of notes and drawings, achieved better results compared to the ones who had less notes and no drawings. It was observed that the subject of geological time was the most challenging subject for the students. This may be due to the fact that the subject of geological time is discrete, that it takes place over very long periods of time, and that there is no prior knowledge of the subject. Two of the drawings made by the students (E and H) in their SWH regarding plate tectonics are shown in Figure 7.

Figure 7
SWH Drawings of Student E and Student H Made During the Seventh Week



The target concepts for the last basic geoscience topic in the implementation process (Destructive natural events) and the review of the working group's SWH and worksheets are given in Table 12.

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Table 12
The Target Concepts for the Last Basic Geoscience Topic

Geoscience subject		Target theme	Student							
			A	B	C	D	E	F	G	H
Destructive natural events (Natural disasters)	Examples of destructive natural events	Earthquake	✓	✓	✓	✓	✓	✓	✓	✓
		Volcanic eruption, flood				✓		✓		✓
		Hurricane				✓	✓	✓	✓	
		Landslide, erosion, tsunami	✓				✓		✓	
		Snowstorm/Typhoon, avalanche					✓			✓
	Drawing									
	Examples of natural events that may cause destruction	Plate						✓		
		Magma, Volcano/Lava						✓		✓
		Fault line, afforestation		✓	✓			✓		
		Climate change/global warming		✓						
	Drawing									
	People and institutions related to destructive natural events	AFAD (Disaster and Emergency Management)	✓		✓	✓		✓		✓
		UMKE (National Medical Rescue Team)	✓			✓				✓
		Geologist, seismologist	✓			✓			✓	
		Meteorologist/Climatologist				✓		✓		
	Drawing									
Number of true answers			8	6	6	8	7	8	7	6

When Table 12 was examined, it was seen that all the students took notes when the subject of earthquakes was discussed. It was also observed that none of the students made drawings of natural disasters in their SWH. When the SWH of the students who answered all the questions correctly are examined, it is seen that they mostly take notes and draw the target concepts of the subject.

At the end of the geoscience education program the SWH and worksheets of the students were examined, and it was observed that the students who took notes and created drawings related to the target concepts gave better answers.

Opinions and Judgments of 7th Grade Students Regarding the Educational Process

Following the geoscience applications, the students were asked which applications were effective in increasing their interest and motivation in science lessons and the reasoning behind it. The answers given by the students are given in Table 13.

Tablo 13
Students' Opinions on Geoscience Activities

Codes			***f***
Out of class- out of school activities			**3 (A,D,G)**
Reason	Affective	Having fun	3 (A,D,G)
		Increasing love for the environment	1 (G)
		Feeling of freedom	1 (D)
	Total		5
	Cognitive	Acquiring new knowledge	2 (D,G)
		Reconciling with daily information	2 (A,G)
	Total		4
	Learning experience	First experience with the practice	1 (A)
	Teaching ambient	Providing an active learning ambient	1 (G)
Total			11
Food related activies			**2 (C,H)**
Reason	Affective	Having fun	2 (C,H)
		Sharing (collaboration)	1 (H)
	Total		3
	Cognitive	Getting information	2 (C,H)
	Learning experience	First experience with the practice	2 (C,H)
Total			7
Doing experiments			1 (F)
Reason	Affective	Having fun	1 (F)
	Cognitive	Getting information	1 (F)
Total			2
STEM acitivies			1 (E)
Reason	Affective	Having fun	1 (E)
		Providing a competitive environment	1 (E)
		Providing excitement	1 (E)
	Total		3
	Learning environment	Providing opportunity to use materials	1 (E)
		Providing the opportunity to experience what it's like to work as an engineer	1 (E)
		Providing a collaborative working environment	1 (E)
	Total		3
Total			6
Microscope examinations			1 (B)
Reason	Affective	Having fun	**1 (B)**
	Learning experience	First experience with the practice	1 (B)
Total			2

When the opinions of the students interviewed for this study were examined, it was seen that out-of-class activities are the most effective way to increase their interest and motivation for the science courses (Table 13). The students explained why out-of-class activities were effective in increasing their interest and motivation for science lessons, and they listed the reasons for this as follows: affective learning (5), cognitive learning (4), learning experience (1) and learning environment (1)One of the students stated that out-of-class activities are fun, increase love for the environment (affective reasons), help acquire new knowledge (cognitive reasons), create real-world experiences and provide an active learning environment (learning environment reasons). The student said the following(G):

> *"…the activities we carried out outside the classroom, for example, teacher, we dug in the garden with a pickaxe to learn about soil components, and we glued the soil samples to the double sided paper tape you gave us. In this way, we actively have fun in class, the activities give us real-world experiences, teacher, we learn further about our environment, and we love our environment more. I think when this happens, science class becomes like real-world experience..."*

The interviewed students were taught about "The structure and formation of the Earth", "Minerals and rocks", "Structure and types of soil", "Plate tectonics" and "Geological time", which are among the activities included in the geoscience application process, in their schools or elsewhere. It is seen that they do not carry out any activities in schools, and the students generally did not have difficulty in the process, but they felt they lacked skills such as interpretation, classification, combining and sorting. This may be caused by the fact that students have not carried out any activities on some subjects before or have no prior knowledge of the subjects.

The interviewed students were asked the following question: *"Are you more curious to find the scientific explanation of phenomena you experience in day-to-day life? What perspectives did this training give you?"*. The answers given by the students are shown in Table 14.

Table 14
Changes in the Perspective of the Interviewed Students

Codes	f
Opinion about subject content	4 (B,C,G,H)
Understanding (recognizing, learning) geological processes	1 (C)
Realizing that you have insufficient/inaccurate information	3 (B,G,H)
Opinions to satisfy curiosity	**8 (A,B,C,D,E,F,G,H)**
Learning about the structure and formation of the Earth	4 (A,D,E,G)
Being able to distinguish rocks	6 (B,D,E,F,G,H)
Getting to know the soil	3 (D,F,H)
Being able to distinguish fossils	2 (E,G)
Understanding the formation of earthquakes	3 (B,D,H)
Gaining a different perspective	4 (A,C,E,F)
Understanding/knowing the world better	4 (D,E,F)
Learning topics that have not been studied before	3 (C,E,G)

According to Table 14, it is seen that the perspective of the interviewed students on the subject content changed (4) and satisfied their curiosity (8). From 8 students aimed to satisfy their curiosity; understand the Earth better (getting to know it, learning), gain a different perspective on objects, learn about the structure and formation of the Earth, distinguish the types of rocks, learn new things (plate tectonics, geological time), distinguish the types of fossils. Student E's opinion is as follows:

> *"Teacher, for example, I was always curious about how the Earth was formed, how it rotates, why we do not feel dizzy, how such heavy rocks do not fall on it, why do they all look different, and the different types of fossils. I learned more about this subject due to this training. At the same time, I learned that the surface of the Earth is divided into plates, and their movement is related to earthquakes. Furthermore, I learned that humans and other living things appeared according to geological periods, all due to this training. This enabled me to know the Earth better and to look at every living and non-living thing in the world in a different way."*

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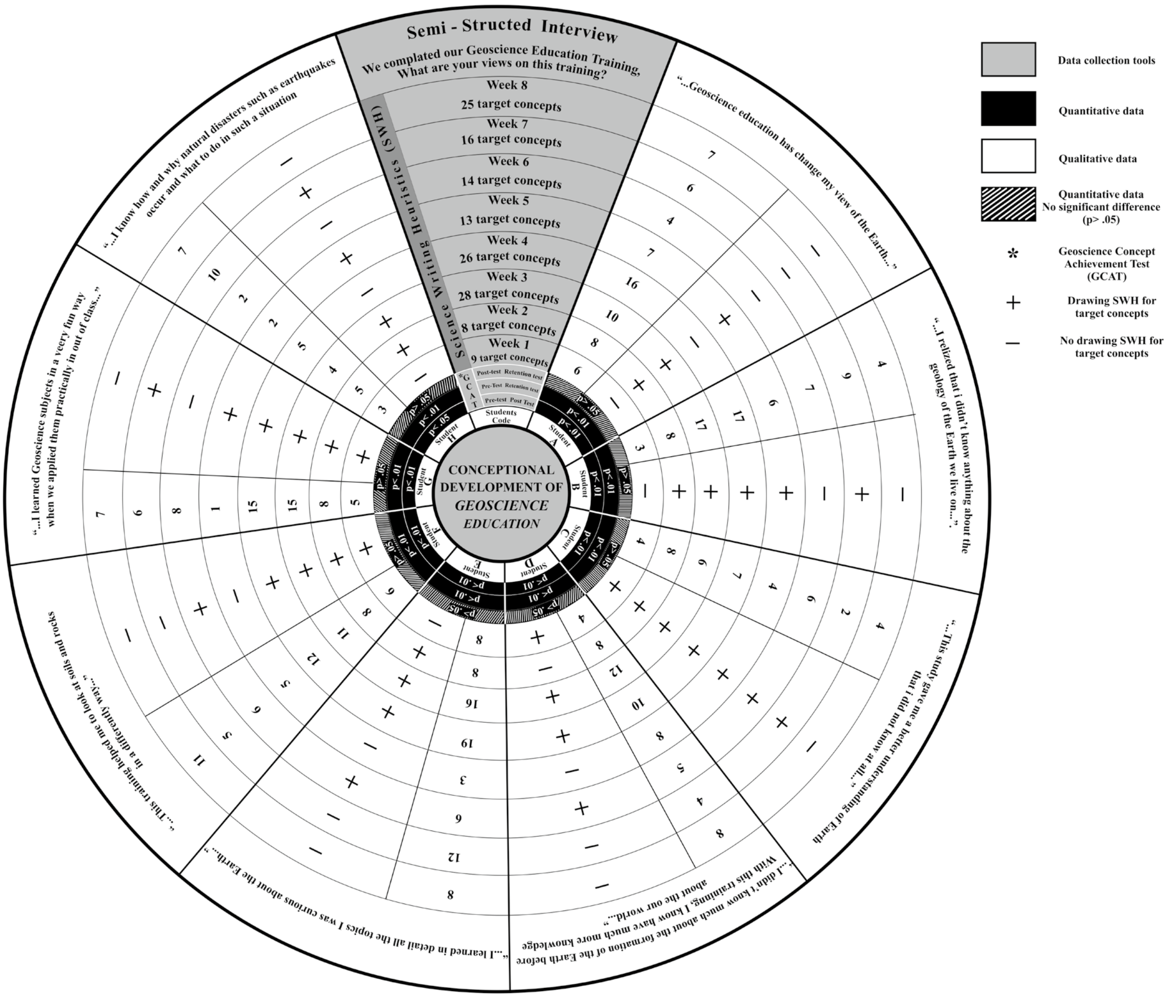
Findings Regarding Joint Display Analysis

The qualitative and quantitative data collected from eight students were jointly evaluated in this part in order to depict the results of the mixed methods research employed in the study (joint display). The applicability of both quantitative and qualitative data was examined during the evaluation process. The data from the qualitative measuring instruments (SWHs, semi-structured interviews) and a quantitative measurement tool (GCAT), which were employed throughout the study process and analyzed jointly at this point, were examined individually in terms of geoscience at this point. The concepts and figures in the SWHs that the students used during the application period (8 weeks) and the quantitative data from the pre-test-post-test and post-test-permanence tests of the GCAT were discussed together with the qualitative data gathered through student interviews in order to assess the conceptual understanding of the eight students who were interviewed on geoscience subjects.

The correlation of quantitative and qualitative data addressing students' conceptual understanding of geoscience subjects is given in Figure 8.

Figure 8

Quantitative and Qualitative Results on Students' Conceptual Understanding of Geoscience Topics



Upon closer inspection, Figure 8 demonstrates the compatibility of the quantitative and qualitative data for geoscience education. The GCAT pre-test-post-test and pre-test-permanence test of the students who took notes and made drawings related to the target concepts in their SWH show a significant difference, at the $p < .01$ level.

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Nonetheless, student H's GCAT pretest-posttest data showed a significant difference at the $p< .05$ level despite his minimal use of the SWH. Upon analyzing the GCAT pretest-permanence test results, a noteworthy distinction ($p< .01$) was seen in the conceptual comprehension of geoscience instruction among all students. Recent student interviews provide more evidence in favor of this claim. In the most recent interviews, when asked about the education they received regarding geosciences, students said:

- it changed their perspective of the Earth,
- they have a better knowledge of the stones and soil they come across daily,
- they learned about subjects they had never heard of (plate tectonics, geological time)
- they understand how the Earth formed and other geoscience subjects that they are curious about.

In this regard, it may be claimed that geoscience education positively and permanently impacts students' conceptual knowledge of geoscience subjects.

Discussion

Students' Conceptual Understanding of Geoscience

After analyzing the conceptual understanding of the eight students in the experimental group, it was discovered that the students who drew and took notes on the target concepts in their SWH related to geoscience subjects were able to answer correctly certain questions on the post-test and permanence test, but not all of the questions on the GCAT pre-test. However, it was found that the students who failed to take notes or make drawings related to the target concepts in their SWH gave wrong answers to the GCAT questions pertaining to the same target idea. It is possible to argue that using SWHs helps students remember things better in this situation. Research also shows that taking notes significantly improves memory, speeds up students' review and repetition of material, and stimulates cognitive functions (Boyle & Weishaar, 2001; Piolat et al., 2005). Fender (2003) stated that if effective notes are not taken in class, students' ability to learn and retain information decreases. Students were encouraged to use SWHs to take notes during geoscience-related activities. In this study, it has been determined that students' conceptual understanding of geoscience subjects was positively impacted by their active usage of SWHs, which involves taking notes and drawings on target concepts that are studied throughout the geoscience education program.

Following their training, students' conceptual understanding of geoscience subjects was assessed. It is understood that the majority of the students learned about the Earth's structure and formation, its layers, minerals and rocks, soil's structure and formation, fossils, plate tectonics, and some students even learned about geological time. However, compared to other geoscience topics, it appears that the concept of geological time is little understood. One could argue that the reason for this is that geological time is an abstract concept that involves very long spans of time. It is significant that research studies on geological time have looked into how students' comprehension of big numbers, including hundreds of thousands and billions of years, and the connections between different-sized temporal eras affects their comprehension of geological time (Cheek, 2011; Dodick & Orion, 2006; Hidalgo et al., 2004; Libarkin, 2006; Teed & Slattery, 2011; Trend, 1998, 2001). According to these research studies, it is generally recommended to use new resources to help students acquire time-based thinking abilities by letting them work through relative time-based difficulties and to provide them with research data on the effectiveness of the materials in different educational contexts and systems. Furthermore, it is emphasized that students' perceptions of the significance of geoscience education and geological time are influenced by their content knowledge of geoscience subjects (Cheek, 2011). According to the results of the current study, students' conceptual comprehension of animations that can remain in their visual memory was positively impacted by hands-on, out of class activities that attempted to concretize the concept of geological time.

In literature, there is also a study examining a substantial causal association between the use of visual thinking networks and the development of learning in geoscience. The students who took part in this research study drew network diagrams on paper using colored or black pencils to illustrate the geosciences subjects. In order to depict information linkages, these network diagrams use words (semantic components) and figural elements joined by lines and other connection representations (Longo et al., 2002). Similarly, SWHs were also employed in the current study. Students were allowed to take notes during the geoscience education process, and they also constructed their own SWHs. They drew and colored pictures related to the target topics in their SWHs. In line with the research results, it has been revealed that students' conceptual knowledge of geoscience is positively impacted by their active usage of SWHs.

As advised by the science curriculum (MoE, 2018), the geoscience activities in the current study were created using the inquiry-based teaching methodology. The study employed innovative teaching methodologies, such as computer-assisted instruction, STEM education, and out-of-school-classroom teaching, in alignment with the 5E learning model.

The literature review indicates that teaching geosciences through inquiry-based methods is successful. In their study, Russell and Chiappetta (1981) explored the effects of the inquiry-based teaching method on geosciences courses. The results show that inquiry-based teaching is useful in increasing students' overall success, and is especially effective in facilitating the application of geoscience subjects.

Chang (2001) examined how well students performed in geoscience courses when inquiry-based learning and computer-assisted teaching were combined. The study's findings demonstrated inquiry-based learning in enhancing the understanding and acquisition of geoscience concepts. It is clear from the current study that inquiry-based geoscience education improves the understanding of geoscience subjects when taking into account the students' GCAT posttest scores after geoscience education.

Students' Opinions about Geoscience Education

Following the end of the geoscience activities, the students expressed positive opinions regarding the geoscience activities during their final interviews. They claimed that geoscience education helped them learn large amounts of information about the Earth and the geological processes that have occurred since the planet's formation. Following the weekly interviews, it was found that most students reported enjoying the out of class activities in their geoscience classes, feeling satisfied when conducting various experiments and making microscope observations, learning novel information, and becoming more interested in the science lessons.

It has been discovered that teaching geology to students can make them more engaged in the classroom, stimulate their motivation, and enhance their knowledge, comprehension, and confidence. According to the study, geoscience education can be utilized to teach students about Earth's processes and to use real-world examples to illustrate chemistry and physics principles. This could lead to an increase in scientific literacy and overall interest in science. The findings also demonstrated that while students enjoyed the geoscience process, they also learned many things about the Earth through their observations and experiments, and they developed a more critical eye for the geoscience materials (soil, rocks, and other materials) they encounter in daily life.

According to student assessments of geoscience education, students reported that they struggled with circumstances requiring high-level thinking and interpretation on subjects they hadn't learned much about beforehand, including how the Earth formed. Since the science curriculum includes no learning outcomes on the formation of the Earth, soil types and structure, plate tectonics, and geological time, it is assumed that this finding is a result of the students' lack of prior knowledge in these subjects. However, prior knowledge plays a significant role in out of class learning situations (Falk & Dierking, 2000). Simultaneously, it emphasizes the importance of high-level cognitive abilities including interpretation, analysis, and argument generation (Khishfe et al., 2017). In this context, it is considered that including essential geoscience subjects into the science curriculum at both the primary and secondary school levels, such as the formation of the Earth, soil, plate tectonics, and geological time, will improve students' understanding of these topics and their analytical thinking skills.

Following the geoscience education course when asked what geoscience education provided them with, the students indicated that it satisfied their curiosity about subjects they had never studied before, including the structure and formation of the Earth, how to distinguish rocks, identify different types of soil, detect fossils, and understand the formation of earthquakes. Since geoscience education is associated with large-scale, three-dimensional spatial thinking, it helps in the development of people's mental and scientific processes (Kastens & Ishikawa, 2006). However, according to recent research, more practice and teaching in the geosciences field are required to foster abstract and practical thinking (Kastens et al., 2009). The students who took part in the current study said that they realized they had inadequate or inaccurate knowledge regarding these subjects and that their understanding of Earth's geological processes has improved as a result of geoscience education.

Libarkin (2005b) highlighted that teaching geoscience courses at all educational levels should go beyond a materialistic perspective of the Earth. It is said that in order for students to completely understand these concepts, geoscience education is required, especially the notion that objects will alter and that the mechanisms underlying these transformations are clear. Trend (2000) revealed in his study that secondary school students seemed to be of the opinion that life and the Earth's beginning occurred at the same time. However, a number of studies highlight the need of scientific literacy in understanding that Earth's subsystems have been continuously changing for more than 4.5 billion years (Mayer 1995, 1997; Mayer & Armstrong 1990; Trend, 2000). The purpose of the current study was to examine seventh-grade students' conceptual understanding of geoscience subjects. The implications for developing the minimum amount of scientific infrastructure required for geoscience instruction are highlighted in science education.

Limitations

The purpose of this study was to determine the conceptual understanding in geoscience education levels of seventh grade students. The researcher developed the lesson plans included in the study based on expert-opinion guidance and utilized several innovative methods of instruction (out-of-school learning, STEM, cooperative learning, etc.). Using maximum diversity sampling, eight students from the study group were chosen based on their achievements and gender to investigate students' thoughts on the subjects and their SWH on a weekly basis during the activity. The responses provided by the pupils are based solely on their own thoughts. We hope that this research and investigation ought to start a conversation regarding geoscience education.

Conclusions and Implications

As a result of the research, it was seen that geoscience activities prepared in accordance with the inquiry-based teaching model positively affected students' conceptual developments in geoscience. For this reason, studies can be carried out to increase inquiry-based geoscience activities so that students can be educated about geoscience and make correct decisions about the future of the Earth. At this point, innovative learning and teaching approaches and SWH can be included. In this way, students can be more conscious about geoscience and their awareness of the Earth, which is currently the only habitable planet, can be increased. It is thought that preparing activities for all basic geoscience subjects in the study and evaluating the geoscience concepts in these activities using innovative learning approaches in accordance with the inquiry-based teaching model will make important contributions to the literature.

In order to increase the number of geoscience literate people and improve student scores on international examinations, future research on the visibility of geoscience achievements in geoscience curricula should be conducted. It is important to develop subject-based lesson plans for teaching geoscience and evaluate their efficacy across grade levels. It is possible to support formal and informal resources that will interest learners in geoscience courses. Websites for the supplied materials can be developed to produce high-quality, interactive teaching instruments.

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Declaration of Interest

The authors declare no competing interest.

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