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The Effectiveness of STEM-Supported Inquiry-Based Learning Approach on Conceptual Understanding of 7th Graders: Force and Energy Unit

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ABSTRACT This research examines the effectiveness of the STEM Supported Inquiry-Based Learning Approach on the conceptual understanding of 7th graders. In the study, a mixed-method design was adopted. The research was carried out with 64 students studying in a secondary school. The study used a Conceptual Understanding Test (CUT) and an Interview Form as data collection tools. Quantitative data obtained in the research were analyzed using ANCOVA and T-test. Qualitative data were proceeded by subjecting them to content and descriptive analysis. Examining the study results, STEM Supported Inquiry-Based Learning Approach increased students' conceptual understanding in the experimental group and the Inquiry-Based Learning Approach in the control group. It was determined that the science teaching in the experimental group was more effective in the conceptual understanding of 7th graders. The students stated that the science teaching in the experimental group was fun, created excitement, made them feel happy, instilled cooperation and team spirit, and thought by doing and living. Depending on the results obtained from the research, it was implicated that STEM-supported education should be carried out by determining the engineering design process steps suitable for the middle school level.

Keywords Inquiry Learning, STEM Education, Conceptual Understanding

1. INTRODUCTION

STEM activities are learning processes that include students' knowledge in STEM fields, in-school or out-of-school, and include today's skills. With such activities, it is seen that students learn science and mathematics concepts more effectively and take the information out of the abstract and make it concrete (Göloğlu-Demir, Tanık-Önal, & Önal, 2021). At the same time, it is seen that it is effective in permanent learning as it allows information transfer among fields. While STEM activities are being prepared, they should not be limited to integrating science and mathematics. There is a need to settle a balance among the fields by ensuring equally strong integrations for engineering and technology. STEM activities can be applied to students outside of school as well as in school. It has been observed that the activities carried out in the school are generally implemented within the scope of Science or Science Applications courses, while the activities carried out outside the school are performed under the name of after-school activities, projects, and summer camps. Thus, carrying out the processes that depend on engineering design can be the healthiest method to prepare for STEM activities (Felix, Bandstra, & Strosnider, 2010).

The engineering design cycle, which expresses the engineering design processes described in the Science and Engineering Applications unit in the 5th Grade Science Coursebook published by the Ministry of National Education (MoNE) in 2018, consists of the stages: Determining the problem, imagining, planning, designing, and testing-development. These design cycles are distributed in all textbook units under "Engineering and Entrepreneurship Practices" (MoNE, 2018). Thus, the engineering design in the 5th Grade Science textbook consists of processes: Asking questions, imagining, planning, creating, and developing steps. In this study, the lesson plans developed as a guide for the teacher were prepared following the current MoNE curriculum, taking into account the inquiry learning model. Following this

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model, the engineering design process of Hynes et al. (2011) was taken into account and applied indirectly to the steps in the curriculum. Furthermore, the engineering design process was considered in developing and implementing the activities used in the learning Force and Energy unit.

Force and Energy is a unit that is considered difficult by the students and includes more than one discipline at the middle school level (Yürümezoğlu, Ayaz, & Çökelez, 2009). Also, force and energy are among the critical concepts that students have difficulty structuring (Stylianidou, Ormerod, & Ogborn, 2002). It has been determined in many studies that even after well-operated instructions, most learners are unable to construct kinetic and potential energy, which are types of energy (Coştu, Ayas, & Ünal, 2007; Taşdemir & Demirbaş, 2010). Furthermore, a study found that middle schoolers had misconceptions about mass and weight (Demir & Çökelez, 2012). It was reported that the students do not adequately understand the concepts in the Force and Energy unit, have misconceptions about these concepts, and they contain abstract concepts. It was also mentioned that classical methods were insufficient to remove the misconceptions in this unit (Demir & Çökelez, 2012). In light of this information in the literature, STEM has the potential to enable more understanding in learning the Force and Energy unit. Thus, it is essential to investigate the effectiveness of the STEM-supported Inquiry-Based Learning Approach in eliminating the misconceptions of 7th graders and learning the concepts.

Studies on the STEM approach differ according to the level of education. In this context, it was found that the most studied groups were middle school students (Dumanoğlu, 2018; Irkıçatal, 2016; Savran-Gencer, 2015), teachers, and teacher candidates (Wood, Knezek, & Christensen, 2010). In addition, it was identified that STEM studies conducted with preschool and primary school students were limited (Faber, Unfried, Wiebe, Corn, & Collins, 2013). Therefore, this study was performed because there are few studies on STEM activities (Gülhan & Şahin, 2016; Savran-Gencer, 2015). Furthermore, students focus on conceptual understanding in central exams in Turkey, and the success rate of students is low in this exam. Furthermore, due to the abstractness of the Force and Energy unit concepts, students have difficulties understanding this unit due to many misconceptions. So, this study has importance in eliminating these limitations and problems in the literature. Therefore, the main problem for the research can be phrased as "Does STEM-supported Inquiry-Based Learning Approach has an effect on the conceptual understanding of 7th graders?". Answers to the following sub-problems were sought within the scope of this fundamental problem.

1. Is there a significant difference between the experimental and control groups' total scores of conceptual understanding in the pretest and post-test?
2. Is there a significant difference between the ANCOVA results of the post-test scores of the experimental and control group students?
3. What are the views of 7th graders about STEM-supported inquiry-based science teaching?

2. METHOD

2.1 Research Design

This study, which examines the effect of the inquiry-based STEM approach on students' science concepts, was carried out by adopting the mixed method. The mixed method allows the use of both qualitative and quantitative research techniques in a way that eliminates the weaknesses arising from the method or supports each other (Yıldırım & Şimşek, 2013). The quantitative research dimension consists of a quasi-experimental design to reveal students' misconceptions at the beginning and end of the study. Through the unbiased assignment, one of the classes was assigned as the experimental group while the other was the control group. The quasi-experimental research design allows for the examination of the effect of the application made after the learning activities on the predetermined variables of the two groups that were more or less equal to each other before the applications. In other words, it is in question to examine the reflection of the variables that are assumed to change depending on the application of the post-test scores in two similar groups whose pretest scores are close to each other (Christensen, 2004). In addition, this method is one of the methods that provide the most effective results among scientific methods. In the qualitative aspect of the study, interviews were conducted by adopting the case study method to support the findings reached by the quasi-experimental method and obtain more insights into the teaching process. For this reason, the interviewees were assigned only to the experimental group. The adopted research design in the study is presented in Table 1.

Table 1 CAT implementation process

Group	Pretest	Implementation Process	Post-Test
Experimental	CUT	Hand-On Papers and Lesson Processing + STEM Activities Prepared According to Research Inquiry-Based Learning Approach	CUT Semi-constructed interviews
Control		Hand-On Papers and Lesson Processing Prepared According to Research Inquiry-Based Learning Approach	CUT

2.2 Participants

The study was realized with the participation of 64 students. All participants are between 12-13, and 54.68% are female students. Participants are studying in a public school where families with low and middle socio-economic income levels are densely populated. While 29 participants were assigned to the experimental group, 35 were to the control group. All students were students at a middle school in the 2018-2019 academic year. The participants were determined according to the easily accessible sampling method. The advantages of this sampling method, such as being economical, enabling the comparison among comparison groups, and providing speed and practicality to the research, enabled the use of this sampling type in this study (Çepni, 2011). In the experimental group, ten selected students were interviewed after the implementation. The post-test scores of the Conceptual Understanding Test and voluntariness were considered to select the interviewees. CUT test scores are divided into four quartiles according to the low, medium, and high-class average. Interviews were conducted with three students from the low and high groups and four from the middle group. Due to the ethics of the research, the students were coded as S1, S2, S3… S10.

2.3 Data Collection Tool

The Conceptual Understanding Test (CUT), consisting of 14 open-ended questions and a Semi-Structured Interview Form, was used in the research. These data collection tools are described in detail below.

The Conceptual Understanding Test (CUT)

The researchers developed the CUT. The questions were prepared in line with the "Force and Energy" unit objectives included in the 2018-2019 Science Curriculum to ensure the scope validity of the questions in the CUT. It was submitted to the opinion of three science educators having positions at the university as assistant professors and two science teachers working in the state middle school for 5-10 years to ensure the validity of the CUT, which initially consisted of 22 items. The corrections made due to opinions and suggestions separated some questions into a and b sections, and some were removed from the test. The final version of the test consisted of 14 questions. Thus, CUT was ready for pilot implementation and applied to 70 students in 8th graders. The t-test results for CUT are given in Table 2.

A significant difference was found between the mean scores of the upper and lower groups of 27% in the remaining questions, except for Question 1A, Question 1B, Question 7, Question 9, Question 13A, and Question 13B considering the average of the lower and upper groups. Therefore, questions 1A and 1B, Question 7, Question 9, Questions 13A, and 13B were excluded from the test, looking at the data in Table 2. The final version of the CUT consisted of 10 questions and was implemented as it is. A question in the CUT is given in Figure 1.

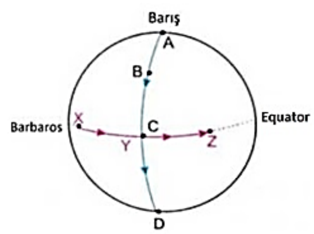
Table 2 T-test results for item means of upper-lower groups of test items

Question #	*Groups*	*N*	*M*	*Sd*	*t*	*p*
1A	Upper Group	19	3.3158	0.74927	1.061	**0.296**
	Lower Group	19	3.0526	0.77986	1.061	
1B	Upper Group	19	3.3158	0.82007	0.404	**0.689**
	Lower Group	19	3.2105	0.78733	0.404	
2	Upper Group	19	3.6316	0.49559	19.298	0.000
	Lower Group	19	0.4737	0.51299	19.298	
3	Upper Group	19	3.3684	0.49559	17.690	0.000
	Lower Group	19	0.4737	0.51299	17.690	
4	Upper Group	19	3.3684	0.49559	20.171	0.000
	Lower Group	19	0.2632	0.45241	20.171	
5	Upper Group	19	3.3684	0.49559	20.171	0.000
	Lower Group	19	0.2632	0.45241	20.171	
6	Upper Group	19	3.3684	0.49559	17.400	0.000
	Lower Group	19	0.3158	0.58239	17.400	
7	Upper Group	19	3.3158	0.74927	1.061	**0.296**
	Lower Group	19	3.0526	0.77986	1.061	
8	Upper Group	19	3.6842	0.47757	19.640	0.000
	Lower Group	19	0.5263	0.51299	19.640	
9	Upper Group	19	3.3684	0.49559	17.690	**0.689**
	Lower Group	19	0.4737	0.51299	17.690	
10	Upper Group	19	3.3158	0.82007	0.404	0.000
	Lower Group	19	3.2105	0.78733	0.404	

Table 3 T-test results for item means of upper-lower groups of test items (*Continued*)

Question #	*Groups*	*N*	*M*	*Sd*	*t*	*p*
11	Upper Group	19	3.3684	0.49559	17.400	0.000
	Lower Group	19	0.3158	0.58239	17.400	
12	Upper Group	19	3.6842	0.47757	19.640	0.000
	Lower Group	19	0.5263	0.51299	19.640	
13A	Upper Group	19	3.3684	0.49559	17.400	**0.701**
	Lower Group	19	0.3158	0.58239	17.400	
13B	Upper Group	19	1.8947	0.45883	0.387	**0.664**
	Lower Group	19	1.8421	0.37463	0.387	
14A	Upper Group	19	1.9474	0.52427	-0.438	0.000
	Lower Group	19	2.0000	0.00000	-0.438	
14B	Upper Group	19	1.4211	0.50726	27.450	0.000
	Lower Group	19	0.4737	0.51299	27.450	

Barbarossa and Barış are traveling to other countries. As seen in the figure below, Barbarossa while traveling the countries along the Equator; Barış has made his journey towards the poles.



a) What do you think, how would the weight change of Barbarossa traveling around the equator be?

b) What do you think, how would the change in mass of Barış travel from the north pole to the equator?

Figure 1 CUT Example of a question in the final version

Interview Form

This study applied a semi-structured interview form to identify the students' opinions on the STEM Supported Inquiry-Based Learning Approach. With the semi-structured interview, the researchers determined the questions to be researched or asked before interviewing the relevant person or people (Yıldırım & Şimşek, 2013). The researchers developed the interview form. The opinions of three assistant professors in science education and two science teachers were taken, and the pilot application was made by making the necessary corrections to ensure the intelligibility of the form. At the end of the pilot application, final arrangements were made regarding the questions' clarity, and the form was given its final form. The semi-structured interview form included five questions. The questions in the interview form are given below.

1. What are your thoughts on the applications made in the Force and Energy unit?
2. What would you like to say about implementing these applications in the "Force and Energy Unit" into other units?
3. Do you think that STEM activities implemented in terms of the "Force and Energy Unit" contribute to your problem-solving skills?
4. What are the points where you have the most fun and difficulty among the STEM activities held in the Force and Energy unit?
5. Do you have any suggestions to make STEM activities more fun and educational?

2.4 Implementation

This study lasted six weeks in the experimental and control groups (24 hours, four hours a week). Courses in the control group were performed regarding the Inquiry-Based Learning Approach. The experimental group carried out activities according to the STEM Supported Inquiry-Based Learning Approach. The researchers prepared the lesson plan and worksheets in both groups regarding Inquiry-Based Learning. In addition, STEM activities prepared by the researcher were applied to the students in the experimental group. The researcher prepared a teacher

STEM Activity Plan and a student worksheet depending on the STEM activities. A total of five STEM activities were developed for the Force and Energy unit. In addition, the experimental group applied a STEM activity every week. One of the STEM activities developed by the researchers in the study is given in Appendix 1, with the evaluation rubric in Appendix 2. One sample worksheet is provided as an example of the activities in the control group in appendix 3. The implementations made in the experimental and control groups are explained in detail below.

Implementation in the experimental group

The courses were performed according to the STEM Supported Inquiry-Based Learning Approach. The researchers prepared five different STEM activities. These activities were applied in the experimental group, respectively; "Let's Build a Bridge," "Bow and Arrow Construction," "Water Slide Construction," "Catapult Construction Competition," and "Boat Construction." In these activities, the students were in groups of four, each time coinciding with their different friends. It was

Table 4 The implementation process of the "Force and Energy Unit" for the experimental group

	Implementations
Pre-Test	Before starting the application, Conceptual Understanding Test (CUT) for Force and Energy unit was applied as a pretest. Students were given one lesson hour (40 minutes) for the CUT.
Activity 1: Let' s Build Bridges	**Introduction:** In each of the activities, the main concepts related to the work they will do were expressed to the students. For the "Let's Build Bridge Activity," information about force weight and bridge force transmission was given to the students. It is explained what should be considered in the construction of the bridge. **Inquiry:** The problem situation for the activity is presented. "People in village A cannot cross directly to the opposite side because of the stream, and they can go up to 10 km from the village and cross from there. The villager reported this problem to the municipality. Upon the proposal of the construction companies interested in bridge construction, the municipality says that it will give the construction job to the company that makes the most durable bridge construction. You are one of the construction companies dealing with this bridge business. You aim to make a bridge model that is the strongest, as cheap as possible, and aesthetically appropriate. Marbles will be used to measure the durability of the model. "Who will be the company that makes the bridge model carries the most marbles as cheap as possible and aesthetically beautiful?" According to the problem, the student bought the materials on the teacher's desk for an imaginary fee. By sharing tasks between students under the name of "group discussion," a draft of the bridge model they will make was drawn under the title of "drawing," and then model making was started under the title of "construction." **Evaluation:** At this stage, the bridge model was scored by calculating its suitability for purpose, usage status, and durability and, accordingly, how much fictitious money it was made, that is, its cost. In the "Change-Development" section, they were asked to write down where they would pay attention if given a chance to make the desired model again. Finally, students were required to criticize themselves under the questions asked in the "Analysis" section.
Activity 2: Bow and Arrow Making	**Introduction:** In each of the activities, the main concepts related to the work they will do were expressed to the students. It explained what the students should pay attention to for "bow and arrow making." **Inquiry:** The problem given for the activity is as follows: "Mustapha lives in the village of Pay. His uncle, who came from City during the summer vacation, bought him a toy bow and arrow set as a gift. Unfortunately, Mustapha broke it while playing with his bow and arrow team friends. Seeing that Mustapha was very upset, his friends wanted to design a bow and arrow with the means at hand. In this case, consider yourself Mustapha's friend. How would you design a sturdy bow and arrow set, as inexpensive as possible and aesthetically pleasing? Your goal is to produce a durable, inexpensive, and aesthetic bow and arrow. According to the problem, the student bought the materials on the teacher's desk for an imaginary fee. By sharing the task between the students under the name of "group discussion," the bow and arrow they will make were drafted under the title of "drawing," and then model making was started under the title of "construction." **Evaluation:** In this section, scoring was made by calculating the suitability of the bow model (by shooting), its use, its durability, and, accordingly, how much fictitious money it was made, that is, its cost. In the "Change-Development" section, students were asked to write down where they would pay attention if given a chance to make the desired model again. Finally, students were required to criticize themselves under the questions asked in the "Analysis" section.

Table 5 The implementation process of the "Force and Energy Unit" for the experimental group (*Continued*)

	Implementations
Activity 3: Water Slide Construction	**Introduction:** In each of the activities, the main concepts related to the work they will do were expressed to the students. It explained what the students should pay attention to for the "water slide." **Inquiry:** The problem given for the activity; "Ali went to the water park with his family on a summer weekend. As soon as he entered the park, he tried all the slides and wanted to find the one that provided the fastest transition to the water. However, while passing from the slides to the water, he noticed none of them was too fast. In the meantime, he thought about what a waterslide should be like, providing quick water access. If you were the owner of the manufacturer company that designed these slides, how would you offer a solution to Ali's problem? Your purpose is to make a model of the slide that is robust, aesthetically beautiful, and as cheap as possible. It provides a quick transition to the water." According to the problem, the student bought the materials from the teacher's desk for an imaginary fee. By sharing tasks between the students under the name of "group discussion," the draft of the water slide they will build was drawn under the title of "drawing." Then model making was started under the title of "construction." **Evaluation:** In this section, the water slide model's suitability for purpose, usage, durability, and, accordingly, how much fictitious money it was made, that is, its cost, were calculated and scored. In the "Change-Development" section, they were asked to write down where they would pay attention if given a chance to make the desired model again. Finally, students were required to criticize themselves under the questions asked in the "Analysis" section.
Activity 4: Building a Catapult	**Introduction:** In each of the activities, the main concepts related to the work they will do were expressed to the students. It explained what the students should pay attention to for "catapult making." **Inquiry:** The problem given for the activity: "You are a catapult master living in the 1350s. You learned that the army would also go to conquer a castle. In preparations for the conquest, you and several masters were asked to make catapults to use in battle. How would you make a catapult? Your purpose; is to make a solid, inexpensive, and visually aesthetic catapult". According to the problem situation, the student bought the materials on the teacher's desk for an imaginary fee. By sharing tasks under the name of "group discussion," the draft of the catapult they will make was drawn under the title of "drawing." Then model making was started under the title of "construction." **Evaluation:** In this part, the suitability of the catapult model for its purpose, its use, its durability, and, accordingly, how much fictitious money it was made, that is, its cost, were calculated and scored. In the "Change-Development" section, students were asked to write down where they would pay attention if given a chance to make the desired model again. Finally, students were required to criticize themselves under the questions asked in the "Analysis" section.
Activity 5: Boat Building	**Introduction:** In each of the activities, the main concepts related to the work they will do were expressed to the students. It explained what the students should pay attention to for "boat building." **Inquiry:** The problem given for the activity: "Boats will race to cross a river. The group that will be the first in this competition takes the boat across the fastest compared to the others' boats. The engine power of the boats will be the same as the competition. Your goal is to get the boat across in the shortest time (fastest). Which team will achieve this?" According to the problem situation, the students bought the materials on the teacher's desk for an imaginary fee. By sharing tasks between the students under the name of "group discussion," the draft of the boat they will build was drawn under the title of "drawing." Then model making was started under the title of "construction." **Evaluation:** At this stage, scoring was made by calculating the suitability of the boat model for its purpose, its use, its durability, and, accordingly, how much fictitious money it was made, that is, its cost. In the "Change-Development" section, they were asked to write down where they would pay attention if given a chance to make the desired model again. Finally, students were required to criticize themselves under the questions asked in the "Analysis" section.
Post Test	After the application, the Conceptual Understanding Test (CUT) for the Force and Energy unit was administered as a post-test. Students were given one lesson hour (40 minutes) for the CUT. At the same time, semi-structured interviews were conducted with the students voluntarily.

evaluated and scored according to the rubric the groups gave during and at the end of the activity. Some visuals are included in Appendix 4 from the products of students. During the study, the applications made in the experimental group are summarized in Table 3.

Implementation in the control group

The courses were conducted regarding the Inquiry-Based Learning Approach. The 7th-grade science textbook of the MoNE was used as a source. The inquiry-Based Learning Approach has been handled in three steps.

During the study, the applications made in the control group are summarized in Table 4.

2.5 Analysis of Data

A study by Abraham, Grzybowski, Renner, and Marek (1992) benefited from analyzing the data obtained from the answers to the Force and Energy Unit Conceptual Understanding Test (CUT) of 7th-grade secondary school students. The CUT, prepared by the researcher, was calculated over 72 points (18 x 4 = 72). Therefore, the total score for each question is 4. While creating the answer key

Table 6 The implementation process of the Force and Energy Unit for the control group

	Implementations
Pre-Test	Before starting the implementation, Conceptual Understanding Test (CUT) for Force and Energy unit was applied as a pretest. Students were given one lesson hour (40 minutes) for the CUT.
Activity 1: Measurement with a Dynamometer	**Introduction:** Does anyone know the difference between weight and mass?", "Is there a relationship between kinetic energy and gravitational potential energy?" "Do you think the gravitational forces of celestial bodies are the same?" the students asked. It was explained to the students that the movement of a person who goes up the mountain is more comfortable, but the movement of a person who lives at sea level is not more comfortable. The reason for this was the focus. The students were asked why an astronaut who went to the moon jumped from the ground higher than on Earth, and the reasons were emphasized. Both cases were based on the same scientific fact, and students were asked to form their hypotheses about the current situation. **Inquiry:** The class was divided into groups of four, and the necessary materials were distributed to each group. They were first asked to fill in the estimation section on the worksheet. The groups then recorded the necessary measurements for the study. **Evaluation:** The values obtained through the activity were compared. It was concluded that as the number of books increased, the numerical values in the measurement increased. It was stated that if this activity is carried out in high regions, it will decrease. The reason for this was the decrease in the gravitational force exerted by the Earth as you go up. The questions in the worksheets were solved.
Activity 2: Comparison of Kinetic Energies	**Introduction:** "How does increasing the mass of a moving object affect the kinetic energy? "How does increasing the speed of a moving object affect kinetic energy?" questions were asked to the students. After the student predictions, case studies related to the activity were explained. Then the students were asked to form their hypotheses about the current situation. **Inquiry:** The class was divided into groups of four, and the necessary materials were distributed to each group. They were first asked to fill in the estimation section on the worksheet. Then it was put into practice. First, one end of the wooden board was placed on the floor, and the other was placed on the side where the three books were placed on top to create an inclined plane. Next, a wooden block was placed at a distance of 5 cm from the ground-contacting the end of the inclined plane. Finally, it was calculated how much the plastic ball and miniature basketball ball sent from the inclined plane moved the wooden block. The same work was repeated by placing four books and the fifth book on the higher side of the wooden block. Data saved. **Evaluation:** At the end of the activity, when the plastic ball and basketball ball were released from the same height, it was observed that the basketball dragged the wooden block more. It was commented that this was due to the large mass of the basketball ball. Furthermore, as the number of books increased, both balls dragged the wooden block more. It was interpreted that the reason for this situation was the increase in height.
Activity 3: Comparing Potential Energies	**Introduction:** "What does the potential energy of an object depend on?" "Does mass affect potential energy?" "Does height affect potential energy?" were asked to the students. Finally, students were asked to form their hypotheses about the current situation. **Inquiry:** The class was divided into groups of four, and the necessary materials were distributed to each group. They were first asked to fill in the estimation section on the worksheet. Next, the basketball ball and the plastic ball were dropped from 50 cm and 100 cm, respectively. Finally, the amount of pitting formed in the sand was measured in each process. **Evaluation:** At the end of the activity, the basketball ball was observed to create more depth in the sand when the plastic ball and basketball ball were dropped from the same height. This is because the basketball ball has more mass than the plastic ball. It was observed that the sand depth increased when the height was 100 cm. It was interpreted that the increase in height caused this situation.
Activity 4: Energy Transformations	**Introduction:** Questions were asked such as "Do you think it is possible to switch between energies?" and "How do we explain the motion of an object released from above when it comes to the ground?". Students were asked to form their hypotheses about the current situation. **Inquiry:** The class was divided into groups of four, and the necessary materials were distributed to each group. They were first asked to fill in the estimation section in the worksheet. Then, the students released the plastic ball in their hands from a height of 100 cm without using force. When he got to the ground, they saw that he had speed. **Evaluation:** The students stated that the object's potential energy when it was 100 cm high turned into kinetic energy when it was on the ground.
Post-Test	After the application, the Conceptual Understanding Test (CUT) for the Force and Energy unit was implemented as a post-test. Students were given one lesson hour (40 minutes) for the CUT.

Table 7 CUT scoring table

Levels of Understanding	Scoring Criteria	Score
Complete Understanding	• Answers that include all aspects of a valid answer	4
Partial Understanding	• Answers that include one aspect of the valid answer but not all aspects.	3
Partial Understanding with a Certain Misunderstanding	• Responses that show a partial understanding of the information but also contain a misconception	2
Misunderstanding	• Scientifically incorrect answers	1
No Understanding	• Answers containing expressions such as leaving blank, "I do not know," "I do not understand," • Repeating the question exactly, • Irrelevant or unclear answers	0

Table 8 Experimental and Control Group CUT Pre-Test and Post-Test Statistics Values

Groups	Tests	N	Min	M	SD	Variance	Skewness	Kurtosis
Experimental	**Pretest**	29	3	8.59	3.09	9.54	0.356	-0.679
	Post-test	29	15	35.24	8.40	70.62	-0.515	-0.317
Control	**Pretest**	35	2	8.20	3.38	11.40	0.439	0.515
	Post-test	35	9	24.20	7.76	60.46	0.051	-1.037

Table 9 Experimental and control group CUT pre and post-test normality analysis results

Groups	Tests	Kolmogorov- Smirnov			Shapiro- Wilk		
		Statistic	Sd	p	Statistic	Sd	p
Experimental	**Pretest**	0.161	29	0.051	0.946	29	0.146
	Post Test	0.134	29	0.194	0.961	29	0.351
Control	**Pretest**	0.133	35	0.124	0.965	35	0.312
	Post Test	0.117	35	0.200	0.959	35	0.217

($p < 0.05$)

for the CUT questions, five criteria were determined for the answer part. These criteria are characterized as "Complete Understanding (4)", "Partial Understanding (3)", "Partial Understanding with a Certain Misunderstanding (2)", "Misunderstanding (1)", and "No Understanding (0)". The scoring method is done as in Table 5.

After scoring, the kurtosis-skewness coefficients and the Kolmogorov-Smirnov (K-S) test were calculated to examine whether the data obtained with CUT in the groups showed a normal distribution. The statistical values of the CUT are given in Table 6.

When Table 4 was examined, it was determined that the skewness and kurtosis values of the CUT pretest and post-test score distributions of the experimental and control groups remained within the normal distribution limits (+2, -2). Therefore, the normality test results are given in Table 7 to provide more information on the normality of the data distribution.

When Kolmogorov-Smirnov values given in Table 7 were examined, it was seen that the CUT pretest and post-test scores of the experimental group were normally distributed ($p < 0.05$). In this context, the dependent group's t-test was used for intragroup comparisons, and ANCOVA was used for intergroup comparisons. The analysis results were presented in the findings section in the tables.

The data obtained from the force and energy unit semi-structured interview were recorded with a voice recorder and transferred to the electronic environment. Later, the data were transcribed and converted into written documents. In this context, the data were simplified by re-reading the written documents and removing the subjects outside the research scope. The data were categorized in the findings section, considering the common and divergent points. In this context, interview data were subjected to content analysis. While performing content analysis, three experts read and coded it. The obtained

Table 10 Dependent groups' t-test results of experimental and control groups CUT pretest and post-test average scores

Groups	Tests	N	M	SD	df	t	p
Experimental	**Pretest**	29	8.59	3.09	28	-19.117	0.000*
	Post-test	29	35.24	8.40			
Control	**Pretest**	35	8.20	3.38	34	-13.387	0.000*
	Post-test	35	24.20	7.76			

($p < 0.05$)

Table 11. Statistics according to CUT post-test scores

Groups	N	Mean	S.D.	Corrected Mean
Experimental	29	35.24	8.40	35.01
Control	35	24.20	7.78	24.39

Table 12 ANCOVA results of post-test scores adjusted for CUT pretests by groups

Source of Variance	Sum of Squares	Sd	Mean of Squares	F	p	Eta-Square
Model	2691.606	2	1345.803	25.069	.000	.451
Pretest	758.157	1	758.157	14.122	.000	.188
Group	1784.182	1	1784.182	33.235	.000	.353
Error	3274.754	61	53.684			
Total	60547.000	64				

($p < 0.05$)

codes and frequencies are presented in the form of a table. In addition, remarkable views and statements about the codes emphasized by the participants are given under the relevant tables in italics and quotation marks.

3. FINDINGS

The Conceptual Understanding Test (CUT) was administered to the experimental and control groups as a pretest and post-test. In addition, the t-test was used for dependent groups to determine whether there was a significant difference between the pretest and post-test scores. The t-test results are given in Table 8.

When Table 8 is examined, it is seen that there is a statistically significant difference between the CUT pretest-posttest mean scores of the experimental group in favor of the post-test ($t_{(28)} = -19.117$; $p < 0.05$). As a result of this finding, the research shows that applied STEM activities effectively develop students' conceptual understanding. At the same time, it is seen that there is a statistically significant difference between the mean CUT pretest-posttest scores of the control group in favor of the post-test ($t_{(34)} = -13,387$; $p < 0.05$).

Since it was determined that the CUT data of the experimental and control groups were normally distributed, ANCOVA was used to determine whether there was a significant difference between the CUT post-test scores of these groups. The pretest scores of the groups from the CUT were determined as covariance and included in the analysis to eliminate group differences and the situation of students being affected by the pretest. The statistical values of the CUT post-test averages of the experimental and control groups obtained at the end of the analysis are given in Table 9.

When Table 9 is examined, it is seen that the post-test mean score corrected for the pretest was X = 35.01 for the experimental group and X = 24.39 for the control group. In this case, it is understood that the conceptual understanding improved more in the experimental group in which the STEM activities were applied than in the control group. However, ANCOVA was conducted to see whether these values differed statistically. The ANCOVA results are given in Table 10.

When Table 10 is examined, it is seen that there is a statistically significant difference between the post-test mean scores according to the CUT pretests of the experimental and control groups ($F1; 61 = 33.235$, $p < 0.05$). In this situation, it is seen that STEM activities create a significant difference between the developmental levels of the conceptual understanding levels of the experimental group and control group students. At the same time, the impact power of the study was found to be 0.353 (in Eta-square). From this point of view, CUT has a moderate effect and is significant.

The views of 7th graders about STEM Supported Inquiry-Based science teaching are given in Table 11.

The analysis of the first question on the interview form, in which students' opinions about STEM activities were collected, is listed in Table 11 under the "Feelings." Participants answered the first question with codes such as "feeling of competing," "feeling of happiness," "feeling of responsibility," "team spirit," "workload," "fear," "fun," "excitement," and "inventive sense." For example, the participant with the pseudonym S4 stated that he felt happy and responsible and expressed his opinions with fun codes. For example, in the interview with S4, "*I am happy when I do the activities. I'm having fun. Because we have been given a task, I take responsibility for it to be beautiful*". Likewise, the participant with the pseudonym S1 said, "*It's fun and exciting… Once we score at the end of the event, it's like we compete. You have to accomplish the part you are responsible for. This is how you feel…*". In addition, almost all participants stated that the activities instilled a sense of fun and responsibility and that they were happy while making the prototype.

The analyzes of the second question in the interview form are given in Table 9 under the "Function of Activities" category. Participants expressed their opinions on the current question with codes such as "making joint decisions," "active participation," "being fun," "achieving your mission," "memorability," and "lack of information/efforts to access information."

Table 13. Themes and codes obtained from students' answers about STEM-supported inquiry-based science teaching

	Codes	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	f
Feelings	The feeling of Being in the Competition	+	+			+			+	+		5
	Feeling of Happiness	+		+	+	+		+		+	+	7
	Feeling of Responsibility	+		+	+		+	+	+		+	7
	Collaborative/Team Spirit		+				+			+		3
	Workload		+				+		+		+	4
	Fear		+				+		+			3
	Fun	+		+	+	+	+	+		+	+	8
	Excitement	+		+		+						3
	Inventive Sense			+				+				2
Function of Activity	Making Joint Decision	+	+				+	+		+	+	6
	Active Participation	+		+	+						+	4
	Being Fun	+				+			+	+		4
	Achieving Your Mission	+				+						2
	Memorability		+		+		+	+			+	5
	Lack of Information/Efforts to Access Information					+						1
Impact on Problem Solving	Creative Thinking	+	+	+	+			+	+			6
	Learning by Doing		+			+	+			+		4
	Detailed Thinking	+									+	2
	Collaborative Work			+	+			+	+			4
	Confidence in the Face of Troubles		+				+			+		3
	Group Work	+							+			2
Fun and Difficult Points	Ignoring the Visuality of the Prototype	+	+	+		+	+		+	+		7
	Testing the Working State of the Prototype	+		+	+			+		+	+	6
	Scoring at the End of the Event	+			+	+	+		+			5
	Being in a Struggle	+		+							+	3
	Making the Prototype Sturdy			+		+	+	+	+		+	6
	Time Keeping	+	+	+		+				+		5
	Making the Prototype the Cheapest				+	+		+				3

Table 14. Themes and codes obtained from students' answers about STEM-supported inquiry-based science teaching (*Continued*)

	Codes	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	f
Suggestions	More event creation	+	+	+		+			+	+		6
	Variety of Materials		+		+			+				3
	Ignoring Costs for Materials	+		+		+	+	+	+	+		7
	Giving Longer Time to the Making of Events		+	+	+	+					+	5

For example, the participant with the code S10 said, "*Of course, yes. Normally, I would learn with a pencil, notebook, or stationary material if it was in a book. If I didn't repeat, I would have forgotten. But here, we are the group decision maker. Thus, through the activities, I do not forget my information, and because I did it, it stays in my mind, I never forget it*". Likewise, if the participant with the code S6, "*We act as a group in events. So, everyone is trying to do their best. By adding something from ourselves, we learn by ourselves*".

The third question of the interview form was given under the "Impact on Problem Solving" category. The participant with code S2 said, "*I started to trust myself in problem-solving. Now, I'm not saying I can't do it when I encounter a problem. In addition, through the activities, I set the rules in my mind by creating and living them*". At the same time, the participant with the code S8 stated his opinion "*If I had done this activity by myself, not as a group, I probably not be able to get it to the end. Because while I approached a problem from one side, my other friends approached it from different directions. Through discussions, I learned how they thoughtfully solved the problem. I noticed that my creativity increased. I can say without hesitation the ideas that seem ridiculous at first and that I am ashamed to say*".

The fourth question of the interview form was analyzed under the category of "Fun and Difficult Points." Participants answered this question as "ignoring the visuality of the prototype," "testing the working state of the prototype," "scoring at the end of the event," "being in a struggle," "making the prototype sturdy," "timekeeping," and "making the prototype the cheapest." For example, the participant with code S3 said, "*The things I like in the activities; I was always in a struggle. I was surprised that time passed quickly. We tried to make the model look beautiful by making it colorful and symmetrical. The most difficult thing was that the prototype worked as desired. If it was not as desired, we could not get points and were upset. We were also afraid that time would not be enough*". In addition to this situation, participant S5 stated, "I had much fun scoring at the end of the activities. It was challenging to pay attention to the robustness, cost, and aesthetic categories, but I had much fun".

The last question of the interview form was handled under the category of "Suggestions." Through the answers, it was revealed that the suggestions reflected in participant statements could be categorized under categories such as "more event creation," "variety of materials," and "ignoring costs for materials." For example, the participant with the code S7 replied, "*The color is crucial. There would be a price difference if I chose the colored one. I think these should not be*". The participant with the code S9 said, "*During the activities, most of the groups were immediately sharing tasks and moving on to the design of model making. However, our group was always slow. I think more time should be given to this. Afterward, we got used to this pace, so we accelerated, but still, much time should be given*".

4. DISCUSSION

First, the pretest and post-test scores of the students in the experimental group were compared in the study. A statistically significant difference was found in favor of post-test scores regarding conceptual understanding (See Table 8). This finding shows that the STEM Supported Inquiry-Based Learning Approach applied in the experimental group increased students' conceptual understanding. The engineering design process effectively prepares STEM activity (Felix et al., 2010). In addition, the activities in the Science textbook since 2018 by the MoNE have been prepared according to the engineering design cycle steps. Using the stages of determining the problem, imagining, planning, designing, and testing-developing the problem is practical during the activities performed in the experimental group.

When the control group students' CUT pretest and post-test scores were compared, a statistically significant difference was found in favor of the post-test scores (See Table 10). These analyses can be interpreted as the fact that the Inquiry-Based Learning Approach applied in the control group effectively conceptualizes 7th graders. This increase in conceptual understanding in the control group is due to the worksheets developed by the researchers. These worksheets were student-centered and focused on concepts. The items in open-ended format were placed in the evaluation stage of the worksheet, and these questions measure high-level thinking skills (Bakırcı & Ensari, 2018). Regarding similar studies, it was concluded that student-centered activities are effective in the conceptual understanding of 8th graders (Bakırcı & Çalık, 2013).

When the experimental and control groups' post-test scores of the CUT were examined, it was determined that there was a statistically significant difference in favor of the experimental group. This situation shows that the STEM Supported Research Inquiry-Based Learning Approach applied in the experimental group and the Inquiry-Based Learning Approach applied in the control group were more effective in conceptualizing 7th graders (See Table 9). In other words, it is understood that the conceptual understanding of the STEM activities applied experimental group improved more than the control group. When the CUT post-test increases of the experimental and control groups were examined, it was determined that the difference between the experimental and control groups was 10.20 in favor of the experimental group. In the ANCOVA analysis of CUT, a significant difference was found in favor of the experimental group between the control and experimental groups' post-test scores. This difference is probably caused by the implementation of the work papers prepared in parallel with the MoNE textbook implemented in the experimental group and the implementation of STEM activities. It is thought that applying more than one way of thinking to the problem solution in the worksheets given to the students and testing them by trying helps to increase their conceptual understanding. It was mentioned that STEM activities improve students' conceptual understanding in many studies (Irkıçatal, 2016). STEM activities have a crucial role in improving students' interest, success, attitude, and motivation and in concluding the problems encountered in daily life (Honey, Pearson, & Schweingruber, 2014). Each activity was prepared by the researcher and started with a problem situation to solve the problem encountered in daily life. By adhering to the engineering design process steps, students tried to solve the concept arising from the encountered problem (Hynes et al., 2011). At the same time, attention was paid to the criteria that the prototype they created should appeal to the eye, be made at a low cost, and be robust. It was emphasized that it is essential to implement and conduct the prepared activities this way (Savran-Gencer, 2015).

In the first question of the semi-structured interview form, the students stated that they competed, felt responsible, and worked in a team spirit. In addition, they stated that they had fun, were excited, and felt like inventors. So, it was the indicator for the activities that are a new practice for the students, they take an active role in the activities, and the idea of being successful in each group contributes to the positive thinking of the students. In addition, it has been determined that STEM-supported science teaching increases students' motivation, develops a positive attitude toward the lesson, and provides effective learning (Yıldırım, 2016). However, some students also underlined that they feared failing to succeed in the task they took during the activity (See Table 11). This situation can be attributed to the belief that some students, who are generally unsuccessful in the lessons, are hesitant to attend and express themselves in a group of friends. Furthermore, Yıldırım and Selvi (2016), in their study with pre-service teachers, identified that the pre-service teachers held both positive and negative opinions on STEM. In this context, although the study group was different in the literature, it can be said that the obtained results were parallel with the results of this study.

In the second question of the interview form, students were required to state opinions on the application of activities in other units. The students who participated in the interview thought positively about the performed STEM applications and agreed on implementing similar activities in other units. The positive thoughts of the students can be interpreted as fruitful that they reach the information themselves during the activity, take an active part in the application, and express their opinions in group discussions. In the interview with the students, it is understood that it is easy for them to learn the subject, the information is permanent, and they learn by having fun. In addition, the worksheet related to STEM activity has some features. These features include giving the problem situation to the students, determining the materials for the prototype themselves, making the prototype with their creativity, and providing the product formation with their efforts. Karahan, Canbazoglu-Bilici, and Ünal (2015) stated that students had an enjoyable learning experience in studies on the STEM education approach.

The third interview question examined the applications' contributions to the students' conceptual understanding level. Students stated that they could think creatively, learn by doing and experience, think versatile and detailed, work collaboratively, and try to solve the problem by relying on themselves in case of a problem through STEM activities. It is effective for students to combine the prototype for the problem given during the activity with their imagination and creativity. In addition, activities such as drawing the prototype of the activity that the students will do and creating a model are effective. In addition, the activities are effective in thinking quickly in the face of the problem, making joint decisions, and trusting themself and their group mate during model formation. Therefore, it has been determined that studies on the STEM approach improve students' creativity and imagination and help them think quickly and produce solutions (Tiryaki & Adıgüzel, 2021).

In the applications made with the fourth interview question, the points that the students had fun with and had difficulties with were questioned. For example, during the STEM activities, the students stated that they had fun decorating the prototype, trying to see whether it worked, and scoring at the end of the activities. On the other hand, they stated that they had difficulties during the prototype construction due to the timing and wanted to avoid cost calculations due to the pricing of materials. It is thought that students' negative thinking is because they want to extend the required time by thinking quickly and creatively to get higher scores during the evaluation, which is evaluated based on the appropriateness of the cost calculation.

The last interview question included the students' suggestions about the practices. The students stated that more activities should be done, the duration of the activities should be extended, and the materials used for the activities should include more variety. It can be said that having fun, being happy, and spending time with their group friends for a purpose is effective the basis of the thoughts of increasing the number of activities of the students. However, insufficient application time can explain the student's requests to extend the activity period. This situation can be associated with students' learning speed and individual differences. In addition, when the reasons underlying the subject of increasing the variety of materials are examined, there is no shortage of tools. For example, they want to buy a colored product to compensate for the time it takes to color material to ensure its visuality.

5. CONCLUSION

The findings obtained through the student interviews supported the quantitative data gathered through the CUT. The students stated that STEM-supported science teaching enables learning by doing and experiencing, that they take responsibility while learning the subject, and that this situation enables learning by having fun. In addition, the students stated that their problem-solving skills improved because they used the engineering design cycle in their activities. It has been understood that the designs made for Force and Energy unit contribute to the effective learning of subjects. In this study, it was concluded that the STEM Supported Inquiry-Based Learning Approach was effective in conceptualizing 7th graders in the Force and Energy unit.

During the formation of the groups, it is recommended that the students should be allowed to form the friends they want in the first activities. Then it is better to form the groups randomly for the subsequent activities. Thus, the heterogeneity within the group will be reflected in the groups, and the responsibility taken by each student and the communication with his groupmates will increase. In this way, it can be ensured that students respect each other.

It is recommended not to show the materials when the activity worksheets are distributed to the groups. It can be instilled that students need to decide on their own which materials they should use for a suitable solution to the problem situation. At the same time, students can be expected to write the materials they want by leaving the materials section blank.

During future activities, it is recommended that the students make the desired prototype by providing more than one feature (resilience, cost, and aesthetics) by their level. At the same time, students can be informed by including the desired features in the evaluation form in the scoring.

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APPENDIX 1: LET'S MAKE BRIDGE ACTIVITY

Grade: 7th Grade
Unit: Force and Energy Unit
Duration: 40+40+ 40+40 Minutes
Materials used
The following materials will be left on the teacher's desk as much as the number of groups. Students will be free to take the required material from the table they believe (You can use the same material more than once. The calculation of the total fee will be made accordingly). The price of each material is listed under the student worksheet. At the end of such an activity, the expenditure of the students for the bridge model will be calculated.

• Background paper	• Adhesive (90ml-60ml)	• Paper Cup
• Cardboard	• Rope	• Pen
• Scissors	• Silicone wick	• Ruler
• Silicone gun	• Marble balls	• Scissors
• Utility Knife	• Tape	• Highlighter

Pricing (TL: Turkish Liras)
Cardboard: 5 TL, Silicone Wick: 1 TL, Silicone Gun+1 Silicone Wick: 30 TL, Background Paper: 3 TL, Ruler: 2 TL, Scissors: 1 TL, Utility Knife: 2 TL, Adhesive 90 ml: 3 TL, Adhesive 60 ml: 2 TL, Pencil - Ballpoint Pen: 2 TL, Highlighter - Thick Tip Pen: 3 TL Rope: (1 m) 2 TL- (2 m) 3 TL, Tape: 2 TL.

Preparation
- Students are divided into groups of 6 people.
- Groups find a group name.

Problem Statement
People in village A cannot cross directly to the opposite side because of the stream. They should go up to 10 km from the village and cross from there. The villager reported this problem to the municipality. Upon the proposal of the construction companies interested in bridge construction, the municipality says that it will give the construction job to the company that makes the most durable bridge construction. You are one of the construction companies dealing with this bridge business. You aim to make a bridge model that is the strongest, as cheap as possible, and aesthetically appropriate. Marbles will be used to measure the durability of the model. Who will be the company that makes the bridge model that carries the most marble, is as cheap as possible, and is aesthetically beautiful?

Research: Ruined or Solid?
- The groups draw the bridges that will examine their durability by designing them on the worksheets.
- They hypothesize how many marbles will be carried by the bridges they produce.
- Each group tests its designed bridges and records the obtained data.
- They discuss the reasons for the collapse of the collapsed bridges. Introduction to the main terms to be learned:

Force: The effect that stops a moving object, makes a stationary object move and changes the shape, direction, and direction of the object is called **force**.

Weight: The gravitational force exerted by gravity on the mass of an object is called **weight**. Weight is a force. Thus, the weight applied by the marble is mentioned.
Transmission of force in bridges: Forces were transmitted and distributed from the upper part to the lower legs, that is, to the feet. It transfers the load collected in the center towards the shores and the bridge piers.
Imagination: Students will be allowed to think about the bridge design. They will conduct peer discussions and brainstorm on constructing a bridge model for durability, aesthetic appearance, and cheapness.
Planning: Each group is going to make a decision on the design procedure for the imagined bridge. They are required to construct a bridge. Materials were provided by the number of groups (For example, if there are five groups, there are at least five of a material). The students take the materials they need according to their designs. Each group member will be responsible for an engineering task (The task can take the form of designing, building, and testing durable bridges).
It should be noted that the estimates are established before the students start the designs. According to the group's decision, the bridge model will be 45 cm long. "Activity evaluation rubric," which indicates the criteria for evaluating students at the planning stage, will be presented to the students with a smart board.
Creating: Students begin to construct the bridge they designed.
Testing: The bridges are tested when the groups have completed their designs. Marbles will be used in testing the durability of the bridge design.
Development: After the groups test their bridge's resistance to weight, the students are asked, "What changes would you make to strengthen the bridge?". Extra time is given if the bridge wants to be improved in design.
Communication: Groups, in turn, explain their bridges to other groups. Meanwhile, groups can ask each other questions about their designs. Finally, after the completion of the build and testing process, the results are discussed.

- Which bridge design was the most durable?
- Are the marbles used in the evaluation considered by mass or weight?
- Which kind of bridge does your model belong to?
- How many marbles could the design bridges withstand?

APPENDIX 2: EVALUATION RUBRIC FOR BRIDGE MODELS

The bridges the groups made will be evaluated according to the rubric below. The group with the highest score will be the winner of the competition.

Categories	Excellent😉	Good😊	Weak☹
1-The group understands the problem situation.	Understands the problem clearly. This point is given if the teacher is not asked a confirmation question about the bridge.	Students ask **one or two** confirmation questions such as "Teacher, can we do this and that?" this point is given.	Students ask **more than two** confirmation questions to the teacher, such as "Teacher, can we do this and that?" this score is given.
2-Group work is done very well.	This point is given if he can get along with his groupmates without problems. (Students are monitored and scored by the teacher throughout the study.)	This point is given if there is a disagreement with the group mates once or twice. (Students are monitored and scored by the teacher throughout the study.)	If the group has a long-term problem in the distribution of tasks among themselves and exhibits behavior that prevents the creation of the product, he gets this score. (Students are monitored and scored by the teacher throughout the study.)
3-The design was an aesthetically pleasing bridge.	This point is given if attention is paid to the absence of adhesive or silicone traces, the symmetry of the cuts, and color harmony in the work on the bridge.	This point is given if the rules of no glue or silicone traces, symmetrical cuts, and color harmony are followed only once in work on the bridge.	This point is given if the rules of no glue or silicone traces, symmetrical cuts, and color harmony are followed only once in work on the bridge or if the product still needs to be finished.
4- The group made the bridge model as cheaply as possible.	The group that makes the cost of the materials the cheapest among the groups gets this score.	When we list the materials cost from the lowest to highest among the groups, the 2nd, 3rd, and 4th groups get this score.	The group that makes the cost of the materials the most expensive among the groups gets this score.

5- The bridge model made by the groups was solid.	If it carries 700 marbles or more, it gets this score.	If it has between 200-700 marbles, it receives this score.	If it takes less than 200 marbles, it reaches this point.
6-The sketch of the group is clear and understandable.	This point is given if the group paid attention to the fine details during the drawing and explained by making explanations.	If the group did not pay attention to the fine details OR did not explain during the drawing.	If the group did not pay attention to the fine details AND did not explain during the picture.
7-The analyzing part of the group is clear and understandable.	The group could notice its positive or negative aspects and express them clearly.	If only the positive or only negative aspects of the group are stated in the analysis section.	In the analysis section, if the group has written a single word, left it, or did not make the necessary explanation.
8-The students' estimations are compatible with the estimation results.	It gets this point if it carries 25 marbles, more or less from the students' guesses.	It gets this point if it takes 50 marbles, more or less from the students' guesses.	From the students' guesses, it reaches this point if it has more than 50 marbles or less than 50.

* In the competition, scoring was based on this formulation: Excellent = 3 Points, Good = 2 Points, Weak = 1 Point.

APPENDIX 3: LESSON PLAN EXAMPLE FOR INQUIRY-BASED LEARNING APPROACH

Course Name: Science
Class: 7th Grade
Subject: Friction force
Objective: 7.3.1.1. Students call the gravitational force acting on the mass weight.
Duration: 4 lesson hours
Tools: 4 dynamometers, four packages, four textbooks

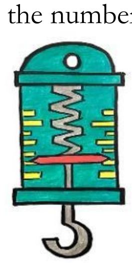
Implementation Steps
Introduction: "Does anyone know the difference between weight and mass?" question is asked to the students. Then, it is explained to the students that the movement of a person who goes up the mountain is more comfortable, but the direction of a person who lives at sea level is not yet. The reason for this is discussed. Next, students are asked why an astronaut who goes to the moon jumps from the ground higher than on Earth. It focuses on why this is the case. It is emphasized that both cases are based on the same scientific fact, and students are asked to form their hypotheses about the current situation.

Inquiry: The "Measuring with a Dynamometer" activity is adapted from the MEB book and distributed to students as worksheets. The class is divided into four groups, and each group is given a dynamometer, bag, and textbook. They are instructed to fill in the forecast section of the worksheet. First, the groups are asked to place a book in the bag, measure it on the dynamometer, and record the data. Afterward, the number of books set in the pack increases, and the measurements are repeated in the dynamometer.

Evaluation: The values obtained as a result of the activity are compared. As the number of books increases, it is concluded that the numerical values in the measurement increase. It is stated that this activity will decrease if it is carried out in high regions. The reason for this is that the gravitational force exerted by the Earth decreases as you go up. Focus on question 1 in the worksheet.

WORKSHEET
"Measuring with a Dynamometer"
1) Prediction:
In the table below, write your measurement value estimates in the dynamometer as the number of books increases.

Number of books	Estimated Numerical Value in Dynamometer
1	
2	
3	
4	

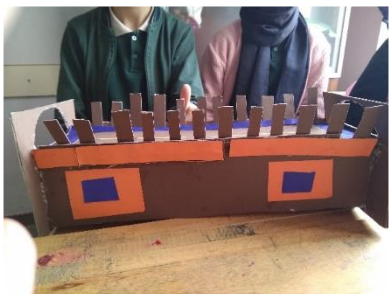


2) Observation:
In the table below, write the measurement values read in the dynamometer as the number of books increases.

Number of books	Numerical Value Read on Dynamometer
1	
2	
3	
4	

3) Explanation:
a) As a result of your estimates and measurements, explain the relationship between the number of books and the reading on the dynamometer.
b) What are your activity's dependent, independent, and control variables?
The dependent variable:
Independent variable:
Control Variable:
Question: Is it possible for the weight of an object weighing 10 kg to be the same everywhere on Earth? Why?

APPENDIX 4: VISUALS OF STUDENT PRODUCTS IN EXPERIMENTAL GROUP




Products of "Let's Make Bridge Activity"


Products of "Bow and Arrow Activity"


Products of "Water Slide Activity"