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Investigating the effectiveness of STEAM education on students' conceptual understanding of force and energy topics

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ABSTRACT

Background: An acronym for 'science, technology, engineering, arts, and mathematics,' STEAM education is an approach that supports the understanding of science content by understanding the skills stimulated by artistic experience. However, only a limited number of experimental studies have investigated the effects of STEAM education on concept learning. Therefore, this paper examines the need for STEAM education to focus on the cultivation of students' conceptual understanding of science content.

Purpose: This study aims to investigate the effectiveness of STEAM education on fostering 7th-grade (aged 13–14 years) students' conceptual understanding of the topics of force and energy.

Sample: The study sample comprised 74 7th-grade students from two different classes in a Turkish secondary school (study group and control group).

Design and Methods: An experimental embedded mixed methods design was used, primarily based on quantitative data, with the qualitative data set embedded within and generally playing a supportive role. A control group was used to determine the role of the STEAM approach in the students' conceptual understanding. A STEAM approach was administered to the study group, while the control group was taught according to the regular science curriculum. Research data were collected with the Force and Energy Conceptual Test and through semi-structured interviews with ten study group students.

Results: The results demonstrate that STEAM education positively affected the students' conceptual understanding and reduced or shifted the number of misconceptions. Furthermore, the study group's post-trial conceptual understanding scores were significantly higher than those of the control group. The interviewees indicated that STEAM education's support for a learner-centered environment fostered the students' conceptual understandings.

Conclusions: STEAM education is useful for understanding concepts. This study contributes to the literature by investigating the effect of STEAM education approaches on students' conceptual understanding.

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Supplemental data for this article can be accessed here.

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Introduction

Recent rapid technological development has resulted in an increasing need for education to assist societies' adjustment to these changes. This has led to the development of new approaches in education, one of which is STEM (Science, Technology, Engineering, Mathematics; Swaby and Ernst 2016).

STEM education is accepted as one of the largest educational movements in recent years, and it contains three instructional approaches: multidisciplinary, interdisciplinary, and transdisciplinary (Drake and Burns 2004; Vasquez, Sneider, and Comer 2013). It is a multi-disciplinary holistic approach that aims to teach students integrally in science, technology, engineering, and mathematics disciplines (Dyrberg and Holmegaard 2018). This approach provides a common theme in which students study in separate disciplines, and the link between the disciplines is limited to the theme itself. In this approach, STEM disciplines are integrated into the teaching environment by establishing connections among their applications (Bybee 2010). However, learning science is not simply about its application. Science is the knowledge of the natural world, including the laws of nature associated with physics, chemistry, biology, earth science, astronomy, and the application of associated facts, principles, concepts, or conventions. Learning science is both a body of this knowledge (content) and a way of knowing as a process (Escalada 2016). STEM education is more than just a combination of its four disciplines in this learning process, and STEM teaching is conducted by using all of these disciplines simultaneously by establishing connections (Bybee 2010).

With interdisciplinary integration, two or more disciplines are combined into a specific concept to achieve the learning objectives. This approach supports deeper learning of a single concept (Vasquez, Sneider, and Comer 2013). Not all of the STEM disciplines need to be included collectively, and connecting two or more STEM disciplines or connecting a STEM discipline with one or more other school subjects constitutes an integrative approach (Sanders 2008).

Transdisciplinary integration provides students with the opportunity to answer fundamental questions in the real world using inquiry, problem-solving, critical thinking, creativity, and innovation (Vasquez, Sneider, and Comer 2013). In this approach, knowledge learned from two or more disciplines are applied to real-world problems and projects; thus, helping to shape the learning experience (English 2016). STEM education is the provision of opportunities for individuals to have direct experiences, learn problem-solving skills, and engage with real-world problems (Zan 2016). According to Çorlu, Capraro, and Capraro (2014), STEM education is formed by teachers' and students' interests and lives, and it means teaching knowledge and skills specific to the central discipline by integrating them with at least one other STEM discipline. In this transdisciplinary study, while science is the central discipline, other disciplines help students learn about real-life problem scenarios.

The integrated STEM approach helps to increase students' understanding (Kuenzi 2008). This is reflected by the tendency, in recent years, to place STEM teaching at the center of reform studies in education. Guzey et al. (2017) explain that the purpose of STEM integration is to: (a) expand students' understanding of STEM disciplines by contextualizing concepts, (b) develop students' understanding of STEM disciplines through exposure

to socially and culturally accordant STEM contexts, and (c) enhance students' interest in STEM disciplines to enlarge their perspective of STEM fields.

In Turkey, interest in STEM research has recently begun increasing. Turkey's new 2017 draft middle-school curricula also focused on STEM education and engineering skills. Science curricula (Vasquez, Sneider, and Comer 2013) emphasize that students should develop the skills and abilities necessary to solve everyday problems scientifically. However, STEM is not included in this program (Vasquez, Sneider, and Comer 2013). STEM education is an evolving process in Turkey and not yet fully integrated into the curriculum, and a more qualified and comprehensive implementation of STEM education is necessary.

In 2011, Korea's Ministry of Education, Science, and Technology (MEST) proposed a STEAM (science, technology, engineering, arts, and mathematics) model by adding the fifth discipline, arts, to STEM. This modification of STEM to STEAM was based on findings that creativity improved science education (Burnard 2015). STEM focuses more on mathematics and science and encourages teamwork more than collaboration. STEAM takes a broader view and includes computer graphics, performing arts, creative planning, and even playful problem solving, while researching and designing solutions, enabling an aesthetic perspective on daily life (Jolly 2014). While STEM is considered as logical, analytical, and useful; art is considered as intuitive and emotional (Vande Zande 2010), and has provided a new motivation for STEM by increasing creativity, problem-solving skills, memory, motor coordination, and analytical skills (Sousa and Pilecki 2013).

Integrating arts into science education enables affective and cognitive learning (Abed 2016; Stagg 2019; Stagg and Verde 2019). STEAM education encourages students' problem-solving skills and interest in science and technology through real-world applications (Jeong and Kim 2014). Stagg and Verde (2019) noted the value of integrating arts-based activities into science education for generating effective learning, and STEAM education research in Korea has demonstrated an increase in the understanding of science content and students' ability to understand imagination and artistic emotions (Jho, Hong, and Song 2016). Moreover, in Korea, STEAM education is considered an effective way to develop students' creativity (Kim and Kim 2016). As there is a high correlation between creativity and students' achievements (Nami, Marsooli, and Ashouri 2014), integrating STEM with arts can also enhance student achievement.

STEAM education is based on a constructivist approach and places students at the center of learning (Gross and Gross 2016). In constructivist approaches, individuals construct knowledge, as opposed to behaviorism and cognitivism, where rules and knowledge are acquired (Fosnot 2005). This approach allows for 'a different way of perceiving and knowing and dealing with the world, as a means to expand the toolbox of science and engineering' (Wynn and Harris 2012). Like STEM, it focuses on the connections between disciplines initially perceived as different; for example, focusing on the creative design process that is basic to engineering and art (Bequette and Bequette 2012). Thus, STEAM education includes the arts and design as an important part of the educational process, while preparing students for the twenty-first century where creativity is emphasized (Gross and Gross 2016).

Combining arts and science encourages students to learn each discipline and develop the lifelong skills and creative perspectives necessary outside the classroom (Sousa and Pilecki 2013). Thus, as the arts embrace the four Cs (creativity, communication,

convergence, and caring) into education (Choi, Lim, and Son 2017), STEAM integrates these skills into education, and provides teachers and students with the opportunities to engage in complex and integrated teaching and learning opportunities (Steele and Ashworth 2018).

Theoretical framework of the research

As part of national education reform, in 2009, an integrated STEAM curriculum was developed and implemented in Korea in 2009, and in 2011, the Korean Ministry of Education announced STEAM education as a fundamental education policy (Baek et al. 2011). Compared to STEM education, STEAM remains relatively unexamined, but studies of STEAM continue to increase across the world (Kim and Bolger 2017). With the rising interest in STEAM education, some studies have examined its perceptions and practices (Choi, Lim, and Son 2017; Gross and Gross 2016; Jeong and Kim 2014; Jho, Hong, and Song 2016; Kim and Kim 2016; Oh, Lee, and Kim 2013) and suggest that STEAM education is necessary and important. Some studies have also been conducted on conceptual learning (Abed 2016; Bailey and Watson 1998; Metcalfe et al. 1984; Stagg 2019; Stagg and Verde 2019). For example, Abed (2016) examined the effect of drama-based science teaching on middle-school students' understanding of heat topics and their attitudes. Bailey and Watson (1998) investigated the effect of a strategy based on drama/role play on 7- to 11-year-old students in developing an understanding of basic ecological concepts. Stagg (2019) studied the impact of immersive drama on middle-school students' knowledge about biological classification and attitudes towards plants. Stagg and Verde (2019) investigated the effect of an interactive theatre performance on middle-school students' understanding of plant reproduction and attitudes towards plants. As a result of these studies, it was concluded that integrating arts into science education provides conceptual learning. Nevertheless, there is a lack of experimental studies investigating the effects of STEAM education on concept learning.

This study contributes to the literature by investigating the effect of hands-on STEAM education activities on students' conceptual understanding of the topics – force and energy. Hands-on learning is learning by experience, handling scientific instruments, and manipulating objects (Holstermann, Grube, and Bögeholz 2010). The STEAM education learning approach employed in this study can inform educational researchers, teachers, and curriculum developers on the need to implement constructive approaches that facilitate students' understanding of scientific concepts. In this research, instead of off-the-shelf STEAM sets, we use prepared activities on force and energy that are easily available. If the results of these activities are positive, it will encourage the use of concept teaching and demonstrate that STEAM education does not have to be applied solely with sets.

STEAM education comes from a re-conceptualization of STEM education, although it has different benefits and objectives (Quigley, Herro, and Jamil 2017). Therefore, it is first necessary to understand the theoretical background on which STEM is based. Although the optimal approach to STEM education is to apply integrated programs in which all STEM disciplines are highlighted, in reality, it is difficult to realize this in terms of the practical applications of formal education. Hence, the current structure

of schools and teaching programs is not suitable for the integration mentioned above in terms of gains, content, teaching activities, and evaluation approaches (NAE and NRC 2009). That being the case, one practical approach is to focus on just one or two STEM disciplines (Sanders 2008). There are two different STEM integration models: content integration and context integration. Content integration means combining different STEM disciplines in one activity, while context integration means using different STEM contexts to make content more meaningful (Moore et al. 2014). Moreover, STEAM education offers science education in these contexts more consistent with learners' everyday realities and stimulates a higher interest (Stagg 2019; Stagg and Verde 2019; Warner and Andersen 2004).

In this study, we use context-based integration on the topics – force and energy, taking context from other disciplines (technology, engineering, arts, and mathematics) to make the content more appropriate. While the science content is the basic focus, other contexts help the teacher to place the learning. Thus, this study adopted a science-and-arts-based approach in teaching the topics – force and energy.

Aim of the research

The integration of the arts into science education promoted by STEAM is focused on transformative learning experiences, whereby STEAM fields are presented together (Liao 2016) in the belief that the STEAM approach-based intervention may affect students' conceptual understanding. This study aims to investigate the effect of using the STEAM approach in teaching force and energy topics to 7th-grade students on their conceptual understanding of these topics. A STEAM teaching approach was used with the study group, while a control group was taught based on the science curriculum using a science textbook. We chose the Force and Energy unit of the science curriculum because students mostly have misconceptions about these subjects (Diakidoy, Kendeou, and Ioannides 2003), and they are abstract for the students (Donaldson 2004; Nordine, Krajcik, and Fortus 2011). This unit includes differences between mass and weight, solid-liquid-gas pressure, work–force relationships, energy–work relationships, energy transformation, conservation of energy, and frictional force topics.

The research questions were as follows:

What are the students' respective levels of conceptual understanding before and after the instruction?

What are the students' opinions on the effect of STEAM education on their conceptual understanding?

Methods

Research design

This study uses an experimental embedded mixed methods design, in which the qualitative data set is embedded within and generally plays a supportive role in a trial that is primarily based on quantitative data (Figure 1). Using a concurrent embedded mixed-method provides a thorough understanding of the patterns of instruction by first analyzing quantitative data and then supporting the findings with

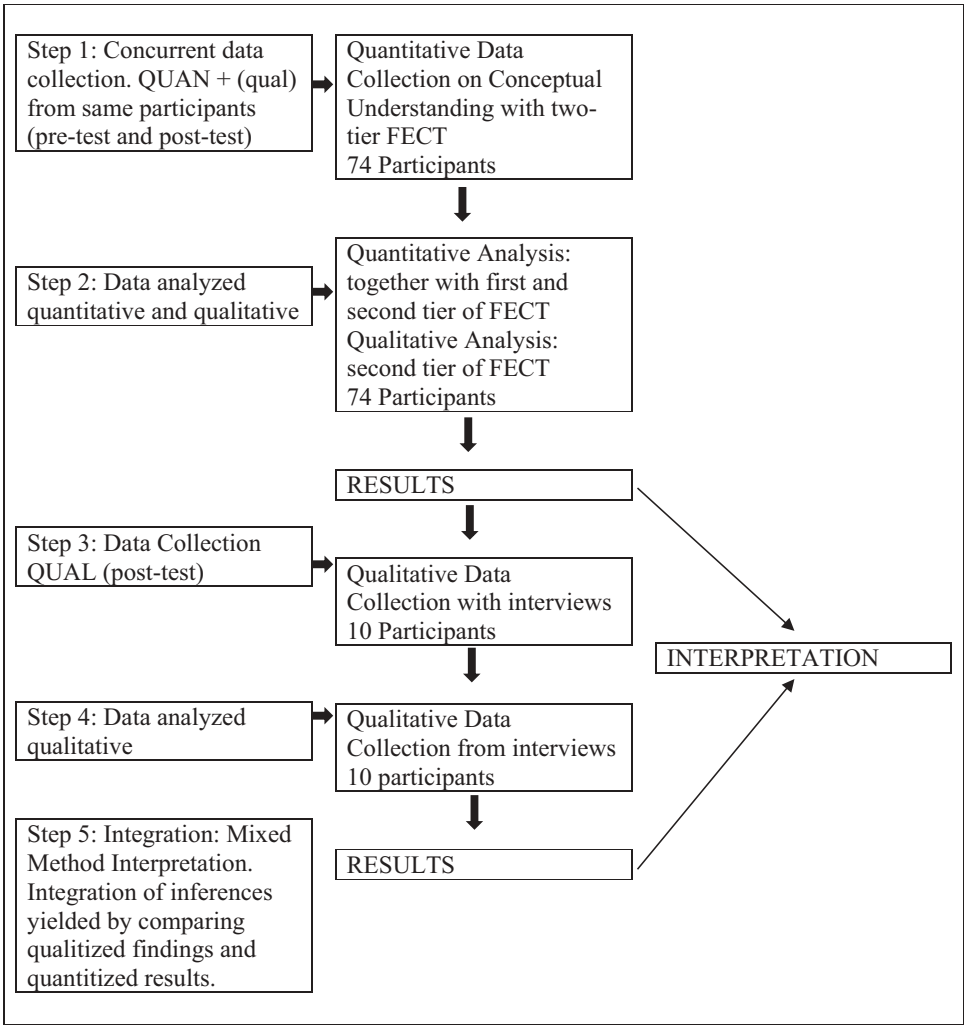


Figure 1. Embedded mixed methods design.

qualitative research findings (Punch 1998). Qualitative data were collected after the intervention. Quantitative and qualitative data were used concurrently at the data collection, data analysis, and data interpretation stages of the study. Given the nature of the embedded design, quantitative and qualitative data were interpreted together (Plano-Clark et al. 2013).

The study was implemented with a study group and a control group. The two groups followed the same curriculum outcomes, but different learning approaches were used. The Force and Energy unit to be taught was introduced to the study group using STEAM activities. The same topics were taught to the control group using the method suggested by the Turkish Ministry of National Education (2013): the activities and examples provided in the textbook (TMNE 2016) were completed, and the unit was taught using teaching methods based on the 2013 science curriculum (plain narrative, questions and answers, and science textbook activities).

Sample

This study was conducted in two 7th-grade middle-school classes in Istanbul, Turkey. The participants' ages ranged from 13 to 14 years. The school was chosen randomly by lot from the list of public schools in Istanbul. As the purpose of the study affected the research group selection, a combination of both convenience and purposive sampling procedures were utilized to generate a sample for both the quantitative and qualitative portions of this study. Convenience sampling was used to select a group of individuals who would be suitable for the study, based on previous knowledge of the population and for the specific purpose of the research (Fraenkel, Wallen, and Hyun 2012). Two classes (of this randomly selected school) with the same teacher were selected (convenience sampling), while the interviewees in the study group were determined according to some characteristics of purposive sampling. The recommended minimum number of participants for experimental studies is 30 in each group (Fraenkel, Wallen, and Hyun 2012). In this study, there were 37 students (16 girls, 21 boys) in the experimental group and 37 students (9 girls, 28 boys) in the control group. Ten students from the study group were selected to participate in the post-treatment interviews: the four students with the highest science grade, the four students with the lowest science grade, and two students who were very interested in the teacher's activities.

All of the study participants provided informed consent, and the study design was approved by the appropriate ethics review board. All measurement tools were presented to the ethics committee of Yildiz Technical University. Following approval, permission was obtained from the Directorate of National Education. Information forms were sent to the students' families and approval obtained for each student. In addition, the teacher declared that they voluntarily participated.

Procedure

The study was implemented in the fall semester of the 2016–2017 academic year and included the Force and Energy unit of the 7th-grade science course. The study lasted 11 weeks (4 hours per week): 9 weeks for implementation and two for testing. A two-tier Force and Energy Conceptual Test pretest and posttest were applied to each group before and after the experiment. The Force and Energy Conceptual Test was developed by the researchers to define the students' conceptual understandings. The implementation began after the pretesting. As an implementation threat can occur when different individuals are assigned to implement different methods, and these individuals differ in ways related to the outcome (Fraenkel, Wallen, and Hyun 2012), the same science teacher taught both groups. After each topic had been completed, the same example questions were given to each of the two groups. The lessons for each group lasted an equal length of time. After the posttest, semi-structured interviews were conducted with ten students.

The STEAM activities developed by the researchers were prepared to reflect the learning outcomes formulated by the Turkish Ministry of Education (2013). Nine hands-on STEAM activities were developed, one for each learning outcome in the curriculum. Table 1 illustrates the distribution of STEAM activities according to content.

In this study, an arts-based approach based on the creative design steps (setting of objectives, planning and designing, analysis of design, making, test, and evaluation)

Table 1. Distribution of STEAM activities according to content.

Activity	Subject Area	Learning Objectives	Tasks
1. Rocket making task	1.Gravitational force	1. She/he describes the weight as a force and measures its magnitude by describing the gravitational force acting on the mass as weight.	1. Making rocket as a member of a team involved space studies
2. Naughty cat	2. Mass-weight	2. She/he makes a determination of center of gravity.	2. Rescuing the naughty cat Papi by designing the highest tower
3. Smart cubes	3. Pressure in solids	3. She/he explores variables affecting solid pressure and analyses the relationship between these variables.	3. Calculating the size of pressure with cubes of various sizes
4. How can I do?	4. Pressure in liquids	4. She/he explores variables affecting fluid pressure and analyses the relationship between these variables.	4. Designing a hydraulic system and calculating fluid pressure
5. It has flown	5. Gas pressure	5. She/he understands applications of air pressure features in daily life and technology.	5. Rescuing from locked tower with parachute
6. I am driving my car	6. Force–work	6. She/he understands that a work is directly proportional with applied force and distance.	6. Calculating the least work by designing car
7. Mission is to design	7. Energy–work	7. She/he classifies kinaesthetic and potential energy.	7. Proving potential and kinetic energy in the competition
8. It is time to prove energy transformation	8. Energy transformation	8. She/he explains that energy can be transformed to each other and concludes that energy is saved.	8. Making wind turbines to observe the conversion of wind energy to electrical energy
9. Let's discover frictional Force	9. Frictional force	9. She/he explores the effect of frictional force on the kinaesthetic energy.	9. Defeating friction force by designing hovercraft tool

presented by the Korean Foundation for Science and Creativity Development was used. In designing the worksheets for the STEAM activities, the steps used by Oh, Lee, and Kim (2013) were taken into account. They developed these steps using the creative design steps set by the Korea Foundation for the Advancement of Science and Creativity, which are characteristics of STEAM education (Oh, Lee, and Kim 2013). They were used in this study as illustrated by Table 2.

In the first step, the students were given a scenario as a problem situation constructed in their minds. For the second step, the students were expected to generate numerous ideas to solve the problem. This step aimed to help the students generate various ideas by asking interrogative and guiding questions about the information that the students would utilize when creating ideas. In the third step, the students planned how to design their solution and drew what they imagined. For the fourth step, they were encouraged to work like a scientist, an engineer, an artist, a mathematician, or experts in technology and they created their designs. Various materials that were as colorful as possible were given to the students to

Table 2. Steps of STEAM teaching and learning.

Step	Explanation
1. Experiencing priming water for an idea	Define the issues and create a goal for an idea on the topic
2. Coming up with an idea	Create and collaborate on a variety of ideas
3. Planning and design fusion	Create a plan to embody the idea and make a design by fusing related studies
4. Making or synthesizing	Make or synthesize products based on science, technology, engineering, and artistic ideas
5. Testing	Test and give feedback or make changes
6. Evaluation	Developing ideas through inter-group evaluation and evaluation

help them use their creativity and to activate the art dimension of STEAM. In the fifth step, the designs were tested in groups, and any designs deemed unsuitable were fixed. In the final sixth step, the students were expected to evaluate the products from the other groups.

In this process, for the aim of developing a creative design, the students were given a problem in which they had to find new ways to explain the science phenomena, make predictions and express or imply the unknowns, and had the opportunity to recommend changes based on their knowledge of the transfer of scientific information. Although the STEM design process includes similar design processes with the STEAM design, the difference is that the design of products and other similar elements in STEAM is based more on aesthetic concerns than on an engineering design cycle, and the designers act in a more artistic way (Bequette and Bequette 2012). To support the students in benefitting from the field of art, a wide variety of design materials were provided in various colors and shapes that are easily available. Classroom discussions were conducted while completing the activities to increase the students' contribution, and the teacher merely guided the students, allowing students to design freely (Figure 2).

After the activities and lesson plans had been prepared, they were examined by four experts: two teachers with more than 10 years' experience in the field and two

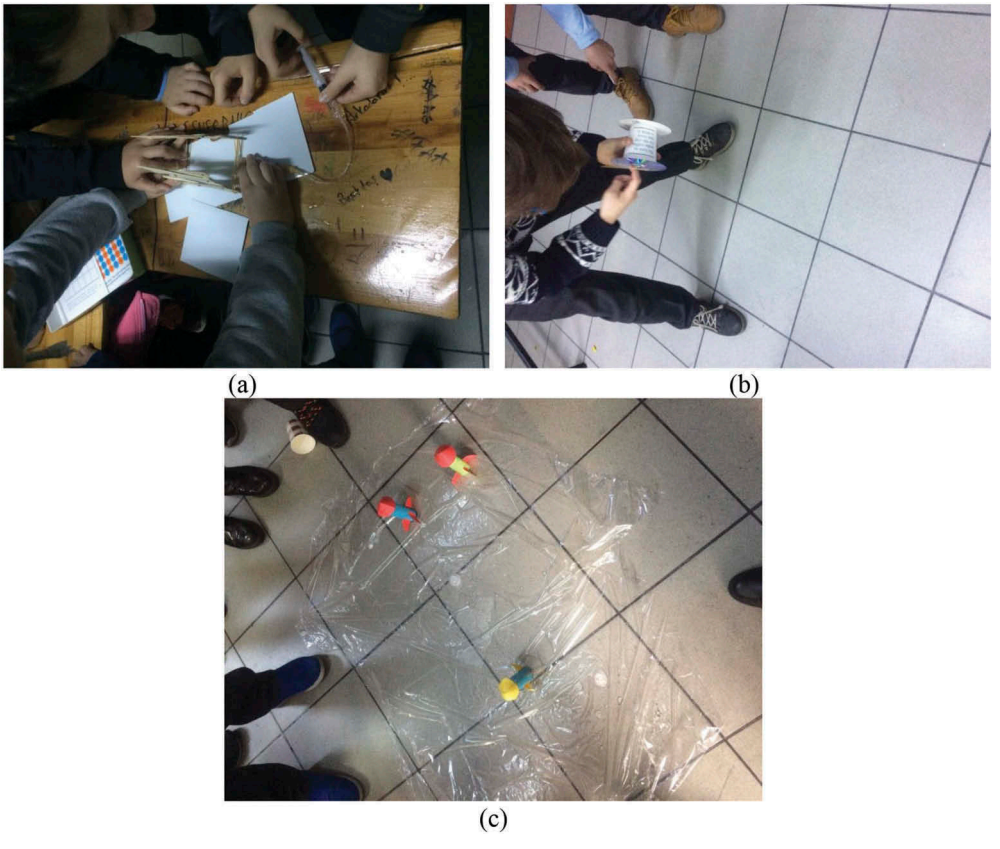


Figure 2. (a) Students are carrying out their designs. (b) Students are testing their designs. (c) Students are evaluating their designs.

academicians specialized in science education. They determined that the lesson plans were appropriate to the students' knowledge and the 7th-grade level.

A pilot run then took place in the fall semester of the 2015–2016 academic year. Two sets of middle-school 7th graders were randomly selected for this study. There were 35 students (15 girls, 20 boys) in the experimental group and 39 students (9 girls, 30 boys) in the control group. One researcher carried out the study and control group procedures with these classes, but few changes were made after the pilot run. Some areas that the students had difficulty in understanding were rearranged, and the duration of some activities altered.

Study group treatment

In the STEAM group, the worksheets were prepared in accordance with the lesson plans and began with a task. A volunteer student was asked to read the task aloud, and the students then followed the directions on the worksheets. Throughout, the teacher acted as a guide, answered the students' questions, and helped them find correct answers by themselves rather than correcting their mistakes.

The aim was to make the students aware of the task they had to complete. The students were expected to produce multiple responses within the framework of the task and to conduct the necessary research. They were then asked to plan their designs as a group. They determined their needs, imagined the product they were planning, and drew their designs. After obtaining the necessary materials, they designed and tested their products. As mentioned above, once all of the groups had exhibited their products, they were evaluated as a class.

Control group treatment

In the control group, the teacher asked the students questions at the beginning of the lesson to motivate them. The lecturing method was then used, with the teacher playing an active role in the lessons. In this group, the teacher followed the activities provided in the textbook.

Data collection

Force and energy conceptual test

The two-tier Force and Energy Conceptual Test was developed to measure the students' conceptual understanding of the topic. The first tier consisted of a multiple-choice question, and the second tier consisted of an open-ended question. Students' conceptions could be examined in depth using open-ended questions as the second tier of the two-tier test (Treagust and Chandrasegaran 2007). The developed test is presented as a supplementary file (Supplemental File 1).

In developing the Force and Energy Conceptual Test, to enable content validity, items were prepared in parallel with the middle-school 7th-grade instruction program learning outcomes set by the Turkish Ministry of Education (2013). The initial version of the test comprised 30 questions with four choices for each test item (one correct answer and three distractors) and an explanation section. To ensure content and face validity, three science teachers with more than 10 years' experience and three science education faculty members examined the Force and Energy Conceptual Test. Each specialist evaluated the test independently, finding only minor spelling mistakes. In line with the opinions of the

specialists, it was established that the prepared texts were appropriate to the students' academic level and knowledge.

First, the pilot study of the test was launched. The initial version of the test had 30 items. In the fall semester of the 2015–2016 academic year, the test, within the scope of reliability studies, was administered to 205 students in three middle-school 7th-grade classes.

The Cronbach's alpha coefficient was calculated for the test's internal consistency and at 0.793 indicated the test was satisfactorily reliable (0.70 is generally considered necessary for reliability; McMillan and Schumacher 2001). At the end of the validity and reliability process, the test contained 19 items, with a total score ranging from 0 to 57.

One-to-one interviews

After the STEAM instruction, ten students in the study group were given one-to-one semi-structured interviews, ranging in length from 20 to 30 minutes, to clarify how they evaluated the design, implementation, and process. They were also asked questions to reveal their understanding of the concepts in more detail. All of the interviews were conducted by the same researcher.

The semi-structured interview questions were as follows: Do you think STEAM education is effective in learning the concepts from the Force and Energy unit and why? Where do you think this effect stems from? How do you think interdisciplinary approaches affect the learning of the concepts from the Force and Energy unit? Do you think that this approach used to learn the concepts from the Force and Energy unit led to a change in your interests and why? Is there anything you would like to add about how this learning approach improved your conceptual understanding?

Data analysis

The criteria for answers suggested by Coştu and Ayas (2005) were used to analyze the data gathered from the Force and Energy Conceptual Test (see Table 3).

In each Force and Energy Conceptual Test item, there was one possible correct answer for each question and reason, while the other answers contained misconceptions; therefore, the students' answers were analyzed to identify their conceptions based on the pretest and posttest. The second tier of the tests that included the pretests and posttests were analyzed by the researcher. Then, a different researcher analyzed the second tier of the tests. The inter-rater reliability coefficients between the scores given by the two raters were 0.94. The researcher also reevaluated these tests after 6 months and measured the intra-scorer reliability coefficient as 0.92. As a result of all these efforts, it was concluded that intra-rater and inter-rater reliability were achieved.

To test the main and interaction effects of the factors while the effects of the covariate-(s) are controlling, ANCOVA was applied after the implementation. ANCOVA is used to test the main and interaction effects of the factors, while controlling for the effects of the covariate(s), and makes four assumptions: normality, equality of variances, homogeneity of slopes, and dependency of scores on the dependent variable. In a Single-Factor Analysis of Covariance (ANCOVA), while determining the effectiveness of the experimental method, if the pretest scores of both groups (study and control) are not equal, the pretest scores are controlled as a covariate. Therefore, a single-factor ANCOVA is a feasible

Table 3. Criteria for analyzing the two-tier test items.

Level of understanding	Criteria for classification of student response	Criteria for analyzing the two-tier test items	Categories Marks
Sound understanding	Responses that involve all elements of the scientifically accepted ideas	True response – True reason (T-T)	3
Partial understanding	Responses that involve at least one of the elements of the acceptable ideas and that show understanding of concepts but that may also contain a misconception	True response – No reason (T-N)/False response – True reason (F-T)	2
Specific misconception	Responses that involve descriptive, incorrect, or illogical knowledge	True response – False reason (T-F)	1
No understanding	Repeats a part of, or full question; irrelevant, not understandable, or inacceptable responses	False response – False reason (F-F)/False response – No reason (F-N)	0
No response	Blank responses and unknown responses	No response – No reason (N-N)	0

and powerful technique for a mixed pattern of pre- and post-experimental measurements with two or more treatment groups (Buyukozturk 2010).

For the interviews, the students' responses were first transcribed, and a data content analysis was then performed by two researchers, who created codes, categories, and themes. The researchers carried out the coding independently, and inter-rater reliability was 95%.

Results

The results obtained from the study data are provided below. Figure 3 displays the totals for both groups' pretest and posttest descriptive results of the conceptual test.

The two-tier results of the Force and Energy Conceptual Test pretest and posttest are presented as a supplementary file (Supplemental File 2) according to the level of understanding (the classification of categories set forth by Coştu and Ayas 2005). Before the instruction, the distribution of students involved in different groups by level of understanding illustrated many differences from each other. The answers given by the groups to the second-tier questions of the Force and Energy Conceptual Test demonstrate their important misconceptions regarding the topics covered. Some students in both groups had a lack of understanding or gave no response at all. After the instruction, the study group's sound understanding percentages were higher in the whole test than those of the control group. In both groups, the percentage of no understanding and no response decreased. Comparing pretest and posttest, both groups' total scores increased in the first and second tiers of the posttest, which was applied at the end of the treatment.

Table 4 illustrates the students' misconceptions from before and after the study period. The specific misconceptions decreased more in the study group, while some misconceptions were eliminated.

To resolve the research problem, two different groups were established, and a Single-Factor Analysis of Covariance (ANCOVA) model of statistics was chosen for the split-plot design encompassing the pre- and post-experiment measurements.

The Mean Scores of the control group (M = 13.59, sd = 6.09) and study group (M = 16.52, sd = 6.64) on the pretest were different. An independent T-Test was used to

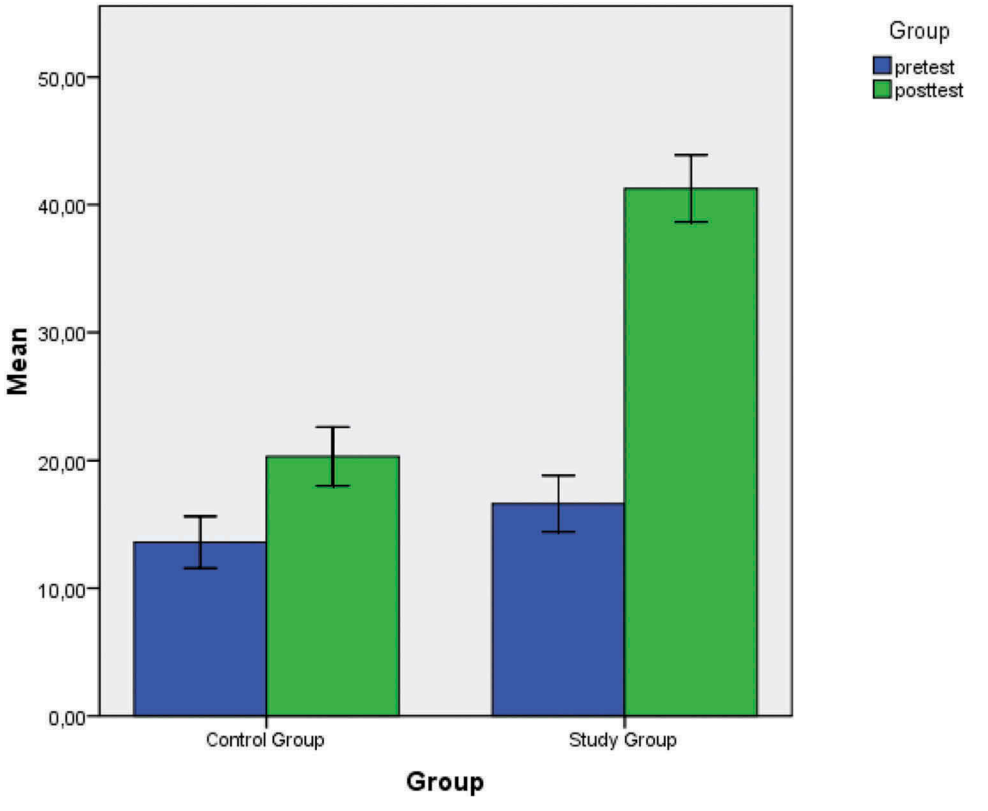


Figure 3. Two-tier conceptual test scores at pretest and posttest, by groups (error bar 95% CI). *For the comparison of pretest scores between the control group and study group, p >.05 and for the comparison of posttest scores between the control group and study group, p <.05.

determine whether the difference between the students' pretest mean scores was significant, and significant differences were found between the groups (t(72) = 2.042, p <.05).

In the covariance analysis performed, the posttest scores on the Force and Energy Conceptual Test were the dependent variable, the pretest scores were the control variable, and the particular treatment (group) was used as an independent variable. All of ANCOVA's assumptions were tested and proved, so the ANCOVA was used to test whether the posttest scores, adjusted according to the pretest scores, demonstrated any significant differences.

The adjusted posttest mean scores of the study group (M = 40.70) were significantly higher than those of the control group (M = 20.89). According to the ANCOVA results, a meaningful difference was found between the posttest conceptual understanding scores adjusted according to pretest scores [$F_{(1,71)}$ = 137.924, p < .05], demonstrating that the students' conceptual understandings were related to the teaching approach applied. In addition, the partial eta-squared value found in this study (η_p^2 = .660) indicates that the teaching approach used had a significant effect on the mean Force and Energy Conceptual Test scores of the study and control groups. The data obtained from the one-to-one interviews were collected under three main themes illustrated in Table 5.

Table 4. Students' specific misconceptions (SM) in the pretest and posttest.

	Control group		Study group	
Misconceptions	Pre (%)	Post (%)	Pre (%)	Post (%)
Mass and Weight				
(1) No gravity force outside the atmosphere.	8.1	-	10.8	-
(2) No gravity on the moon.	18.9	8.1	16.2	2.7
(3) Gravity only has an impact on objects when falling.	8.1	-	5.4	-
(4) The source of force that affects an apple and source of force that affects the moon are different.	13.5	5.4	16.2	5.4
(5) The value of gravitational force, which affects all falling objects, is the same.	27.0	13.5	18.9	2.7
(6) The force acting on an object does work even if the object does not move.	27.0	13.5	32.4	8.1
(7) Mass varies according to where object is.	51.4	24.3	56.8	10.8
(8) Weight does not change according to where object is.	27.0	13.5	18.9	2.7
(9) In airless and airy environments, the mass of the object changes, but the weight does not change.	21.6	8.1	18.9	5.4
Pressure				
(10) Solid pressure does not depend on the surface area of the object.	24.3	8.1	18.9	8.1
(11) Solid pressure does not depend on the weight of the object.	13.5	-	16.2	-
(12) The perpendicular force acting on the unit surface is not dependent on the weight.	13.5	2.7	13.5	2.7
(13) Liquid pressure is highest at the top of the container.	18.9	2.7	16.2	2.7
(14) Liquid pressure is connected to the shape of the container.	16.2	-	16.2	-
(15) The liquid pressure does not depend on the height of the liquid.	24.3	5.4	18.9	5.4
(16) Unable to comprehend the daily life examples of open air pressure.	56.8	13.5	48.6	13.5
(17) We cannot understand the existence of air pressure.	13.5	2.7	13.5	2.7
Force, Work and Energy Relations				
(18) The flexibility potential energy stored in the spring is not dependent on the weight of the object.	18.9	8.1	24.3	5.4
(19) The work depends on the weight of the object.	13.5	8.1	18.9	8.1
(20) The work is not dependent on the length of the path and force applied.	35.1	13.5	24.3	8.1
(21) Kinetic energy depends on the height of the object.	8.1	2.7	16.2	2.7
(22) Kinetic and potential energy depend on the volume of the object.	16.2	8.1	13.5	5.4
(23) Potential energy depends on the velocity of the object.	8.1	2.7	5.4	-
Energy Transformations and Friction				
(24) Friction force always makes movement difficult.	27.0	16.2	21.6	5.4
(25) The frictional force is always opposite to the direction of the movement of the object.	32.4	10.8	35.1	2.7
(26) The frictional force is caused by the roughness of the surfaces.	16.2	-	16.2	-
(27) The friction force always changes the direction of the movement of objects.	35.1	13.5	21.6	2.7
(28) Energy disappears from one energy to another.	13.5	2.7	10.8	-
(29) Standing objects have no energy.	59.5	27.0	51.4	10.8
(30) Energy is used, decreased, or consumed.	16.2	2.7	21.6	-
(31) Friction force always makes movement difficult.	27.0	16.2	21.6	5.4
(32) When an object is left to fall, all of the gravitational potential energy is converted into kinetic energy simultaneously.	18.9	5.4	16.2	5.4
(33) An object that does not move has no energy.	40.5	18.9	24.3	10.8

The first theme, Effectiveness of STEAM education in the learning process for Force and Energy concepts was classified as disliking, liking, or neutral. Most students liked the STEAM approach, although one student was neutral, and one student said that they did not like doing new things. All of the students found interdisciplinary studies important, and only one student did not find these lessons useful. STEAM education was found to increase the majority of the students' interest in science, and the students were also interested in other fields of STEAM at the end of the instruction. A small number of students ($f < 3$) expressed different opinions not illustrated in Table 5. Two students stated that they thought like scientists, engineers, and artists during the activities. One student

Table 5. Categories of students' comments from interviews on understanding with STEAM education.

Themes	Categories	*f*	Examples of comments
Effectiveness of STEAM education in learning process for Force and Energy concepts	Effective learning	8	I liked the lessons that I learned about these subjects because I learned and enjoyed the lesson. We all learned the topics of Force and Energy.
	Producing new things	7	We made new things. We made inventions. I learned to do it because we were doing it ourselves.
	Being fun	4	While every student is waiting for the bell in the other lessons, we wanted to have no breaks in class.
	Motivation	3	When sometimes I did not concentrate on what the teacher was saying, I kept topics in mind with these activities.
	Linking other areas	3	The activities linked Force and Energy topics and other topics and helped us recall.
	Self-awareness	3	I realized that I could think like a scientist.
The importance of interdisciplinary studies in concept learning	Increased self-efficacy	4	Yes, I believe very much in the words 'many hands make light work'. Because they can do everything together by doing an experiment.
	Thought provoking	4	The most important common point of these professions is the power of thought. These professions are both related and connected to each other.
	Providing ease	3	We can easily do it because we work together in the activities. Things get easier if you work together.
	Making better projects	3	We can design better projects together.
Effectiveness of STEAM education in concept learning in students' interest	Want to be a scientist	5	These lessons changed my choices. I want to be a scientist now.
	Enhance engineering interest	4	The engineering activities we did increased my interest in this profession.
	Enhance art interest	3	I liked the design and art.

thought that STEAM education provided retention in teaching, while another stated that their interest in technology increased. Two students said that they wanted to work in the field of mathematics. Only one student said that they did not like the STEAM activities because it forced them to design. In summary, students prefer STEAM education because they can produce new things, it is fun and instructive, they can think like a scientist, engineer, or artist, and they retain information. The interviews, thus, demonstrate that students found STEAM education helpful for their conceptual learning.

Discussion and conclusions

The first research question was the students' respective levels of conceptual understanding, and the results demonstrated that STEAM education had a positive effect on their conceptual understanding. After the instruction, the study group's sound understanding percentages were higher in the whole test than those of the control group. The students' conceptual understanding scores increased from the pretest to the posttest in both groups at a statistically significant level – an expected outcome of the research as both groups received teaching on the topic. There are similar studies in the literature where art-integrated science education has a positive effect on students' conceptual learning (Abed 2016; Bailey and Watson 1998; Stagg 2019; Stagg and Verde 2019).

The second research question concerned the students' opinions on the effect of STEAM education on their conceptual understanding. The interview results indicated that students found the STEAM education helpful for their learning and effective learning, producing new things, having fun, increasing self-efficacy, and the thought-provoking nature of the approach played a key role in supporting the students' learning processes.

As a result of the mixed-method research, it was concluded that STEAM education was useful for teaching the chosen force and energy concepts. As STEAM education supports a learner-centered environment where students actively interact with interdisciplinary knowledge, it fosters students' conceptual understandings. STEAM education provides hands-on experiences that students use to explore abstract physics concepts. This sound understanding realized in middle-school students can make it easier for students to learn science subjects in the future.

In this study, the degree of student participation in the study group was high. This may be because they were allowed to design freely, and this assertion was supported by the interviewees. Thus, the students may have developed a high conceptual understanding as they participated willingly in the lesson. Another key factor underlying the study results is that they gain hands-on experience. From the responses of the students, it can be concluded that practical experiences improved their affective characteristics such as self-efficacy and self-awareness. The students' creativity was also improved and this may because they were allowed to design freely (Oh, Lee, and Kim 2013), which may, in turn, have enabled their conceptual understanding to be realized because creativity improves creative problem-solving and helps students to reach the best solution quickly (Lin 2011). STEAM education can also support students' understanding because hands-on skills development bridges theory and practice. Hands-on science activities embody the abstraction of the nature of cognitive development, support brain activity through kinesthetic involvement, and increase student motivation (Flick 1993). For these reasons, the students in this study may have developed conceptual understanding.

As curriculum integration combines information with personal and real-world experiences, it allows students to learn more meaningfully (Beane 1995). Meaningful learning occurs when students link their previous knowledge to new experiences and skills in real-world contexts (Brooks and Brooks 1993). Therefore, it is important to determine students' previous concepts and to correct any misconceptualizations.

Force and Energy is an area in which many students have misconceptions because it is an abstract topic (Yürümezoğlu, Ayaz, and Çökelez 2009). The prevalent misconceptions in the literature ('Energy is consumed and reduces or runs out,' 'Objects that do not move have no energy,' 'Energy is lost when it is transformed from one type to another,' and 'Energy is a force'; Donaldson 2004; Nordine, Krajcik, and Fortus 2011; Yürümezoğlu, Ayaz, and Çökelez 2009) and the misconceptions found in this study are similar.

Although no extant experimental studies have yet investigated the effect of STEAM education on direct conceptual understanding, there are studies showing that STEM education has a positive effect on students' learning. Ceylan and Ozdilek (2015) investigated the effectiveness of STEM education on students' academic achievement, comparing STEM-based and constructivism-based approaches and demonstrating that the study group's academic achievements were higher than those of the control group. Moreover, Guzey et al. (2017) highlighted the effect of engineering design-based STEM instruction on the learning and achievement of 4th–8th grade students. At the end of their quasi-

experimental study, although single-level analyses of science outcomes demonstrated a meaningful treatment effect for heat transfer topics, multilevel analyses produced no significant treatment effect. Young et al. (2011) compared the achievements of 9th-grade students in STEM schools and traditional schools in Texas and found that students from STEM schools scored higher on a high-stake mathematics test. Although there is no comprehensive experimental study examining the effect of STEAM education on conceptual understanding, there are studies (Abed 2016; Bailey and Watson 1998; Metcalfe et al. 1984; Stagg 2019; Stagg and Verde 2019) that found that integrating art into science education increases conceptual understanding.

It is important to note that there is still much to be learned about the nature of STEAM education and the variables involved. The results of this study provide some perspective in terms of integrating STEAM, and the following recommendations can be made.

The most important contribution that science educators and teachers can make in STEAM education is to provide an environment that increases the likelihood of creativity. Students' motivation should be kept high; their work and willingness are crucial to the success of the design process. The tasks given at the beginning of the STEAM design process should include daily life problems, be appropriate to the students' age and level, and be able to hold their attention. In addition, an important point at this stage is to develop problem situations to which many solutions are possible.

Developing new activities will make important contributions to the literature, and diversifying the activities used in STEAM education research by implementing them with different class levels and units will contribute to the improvement of teaching processes in schools. Another recommendation is to focus more on practice for lessons in STEAM fields and to improve STEAM activities by closely following new developments in science and technology.

The limitations of this study include the relatively small size of the sample. In future studies, the effect of STEAM education on conceptual understanding can be evaluated by applying different numbers and age groups. In this study, the conceptual understanding levels of STEAM education in force and energy were examined. Similar studies should be conducted in other science subjects to consider further the impact of art on learning in STEM.

Disclosure statement

There are no conflicts of interest to declare.

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