International Journal of Psychology and Educational Studies, 2021, 8 (3), 128-139

www.ijpes.com

International Journal of Psychology and Educational Studies

An Investigation into the Development of the Force and Energy Unit through STEM Integration in Science Course and its Effects on Students' Critical Thinking Skills

İsmail EVCİM[1], Mustafa ARSLAN[2]

[1]*Science Teacher, Ministry of National Education, Istanbul, Turkey,* 0000-0002-9567-8935

[2]*Faculty of Education, Yildiz Technical University, Istanbul, Turkey,* 0000-0002-8625-6546

ARTICLE INFO

Article History:
Received 31.01.2021
Received in revised form 10.03.2021
Accepted 20.04.2021
Available online 01.05.2021
Article Type: Research Article

ABSTRACT

In this study, to examine the change in individuals' critical thinking skills, a new unit was developed in which STEM was integrated. The outcomes of this 7th-grade unit were selected from related disciplines. During the learning process of the developed Force and Energy unit, it was aimed that individuals could make judgments by gaining critical thinking skills and evaluate events in a multi-dimensional way. In this study, which lasted for five weeks, the developed unit was used to conduct lessons with the experimental group (N=25) while the control group (N=25) was traditionally taught. The Critical Thinking Scales developed by Demir (2006a) were used in the research process. Before the implementation, no significant difference was found between the experimental and control groups regarding critical thinking skills, but after the implementation, a significant difference was observed in favour of the experimental group. When the scores obtained from the sub-scales (interpretation and explanation) were compared, a significant difference was found in favour of the experimental group. When the changes in the experimental and control groups were examined, there was no significant change in the control group students, but a significant change was found in favour of the experimental group. These changes occurred in the evaluation, Interpretation, and explanation sub-scales of the critical thinking scale. Based on these data, it can be said that the critical thinking skills of individuals who receive STEM education improve. Accordingly, making use of different disciplines simultaneously while designing a product in STEM education is an important factor in the development of individuals' critical thinking skills. Thus, teachers should carry out this process effectively.

Keywords:
Science education, STEM education, STEM unit development, critical thinking, force and energy unit

1. Introduction

The current era is a period in which scientific knowledge and technology advance at an extraordinary pace. It is crucial to transfer the theoretical structure of knowledge to daily life and to realize its practical applications. In this period, individuals will develop their 21st-century skills and thus contribute to the future (Çınar et al., 2016). Wagner (2008), who is in contact with various organizations to raise individuals with 21st-century skills, states that seven skills, including critical thinking skills, came to the fore. According to Demir (2006b), individuals should blend the information with their own thoughts by filtering them through criticism before accepting it as it is, and critical thinking is significant in realizing this process. Kökdemir (2003) advocates that

* This study consists of a part of the doctoral thesis that is being carried out at Yildiz Technical University.

**A part of this study was presented as a paper at the 2nd International Science, Mathematics, Entrepreneurship and Technology Education Congress (E-Congress).

[1] Corresponding author's address: Yildiz Technical University, Faculty of Education, Istanbul, Turkey,
e-mail: evcim82@gmail.com

Citation: Evcim, İ. & Arslan, M. (2021). An investigation into the development of the force and energy unit through stem integration in science course and its effects on students' critical thinking skills. *International Journal of Psychology and Educational Studies, 8*(3), 130-141. https://dx.doi.org/10.52380/ijpes.2021.8.3.398

individuals with high critical thinking skills use reasoning when making decisions about a situation, while individuals with low critical thinking skills make cursory decisions. It can be stated that a good critical thinker is open-minded, reliable, knowledgeable, questioning decisions, overcoming prejudices, acting fairly, prudently, and willing to rethink to have definite conclusions on an issue (Facione, 1990). Therefore, studies should be conducted in line with this purpose to raise ideal critical thinking individuals. Şenşekerci and Bilgin (2008) argue that individuals' critical thinking skills can be improved through education, warning that this skill should be acquired from an early age.

To train individuals with 21st-century skills, a new learning model was needed in which different disciplines were learned in conjunction with each other and transferred to daily life. In this context, STEM (Science-Technology-Engineering-Mathematics) education has emerged, which creates a multi-discipline by bringing together related disciplines and aims to gain new skills by enabling individuals to look at facts and events from a broader perspective. In STEM education, while individuals design for the solution of daily life problems, they collect information by conducting situation analysis, reveal new ideas by brainstorming, develop a prototype based on these ideas and test whether the prototype developed for the solution of the existing problem works according to the specified criteria (NGSS, 2013; NRC, 2012). Therefore, individuals who receive STEM education take an active part in this process and consider different factors by establishing interdisciplinary relationships, so they gain the ability to think multi-faceted. Also, STEM education helps individuals to have the experience of solving real-life problems in cooperation and find an ideal environment for them to develop solutions to their daily life problems.

As in many countries, for the solution of current and future possible problems, STEM education attracts attention from the business world and is considered essential by the Ministry of Education in our country. Since the business world finds the profile of qualified people in 21st-century skills, it considers STEM education. For example, TUSIAD (2014) states that a more qualified education will be initiated by this means. In the STEM education report published by MEB (2016), STEM education is seen as an interdisciplinary approach covering a large part of the learning process. MEB (2018a) has established the Science, Engineering and Entrepreneurship Practices Directive in the updated Science Curriculum and declared that the subjects should be linked with each other in line with this directive. Accordingly, the science textbooks were renewed in line with the updated Science Curriculum and Directive (2018a), but they were found incompatible with STEM education; thus, it was concluded that they had deficiencies in teaching 21st-century skills (Bahar et al., 2018; Çetin, 2020; Özbilen, 2018; Tezcan, 2019). Some activities in the updated Science textbooks do not have the characteristics of STEM education, and the number of activities related to STEM education is not sufficient (Tozlu et al., 2019). Therefore, in this research, a new "Force and Energy" unit with the integration of STEM education has been developed, considering the gains in the 7th Grade Force and Energy unit in the MEB's (2018) Science, Technology and Design, Mathematics Curriculum.

For individuals to realize meaningful learning, it is ideal for creating a program by establishing connections between different disciplines and associating them with daily life problems (Yıldırım & Altun, 2015). In the updated Science Curriculum, MEB (2018a) emphasizes acting with an interdisciplinary perspective based on research and inquiry-based learning. In Mathematics Curriculum, MEB (2018b) states to establish a connection with daily life and associate it with other lessons for this purpose. In the Information Technologies and Software Curriculum, MEB (2018c) underlines that in the progress of the products and projects to be developed, the relevant problems and solutions should be from real life and in this direction should be associated with other courses. In Technology Design Curriculum, MEB (2018d) emphasizes that it is necessary to cooperate with many disciplines, especially the Science course, so STEM-based implementations should be carried out. Therefore, STEM education that attracts attention today emerges based on teaching the disciplines of Science-Technology-Engineering-Mathematics by integrating them (Gülhan & Şahin, 2016). In STEM education, there is an environment in which different disciplines are learned in conjunction with each other at the same, time and there is an approach that considers more than one discipline while making designs for the solution of a problem. Bahadır (2018) advocates that Mathematics courses should not be seen as a collection of arithmetic operations, and implementations should be made by establishing connections with real-life and different disciplines. In another discipline (Technology education), it is said that a multi-disciplinary curriculum will help individuals to comprehend the interconnections of subjects in the learning process

(Wicklein & Schell, 1995). As interdisciplinary relationships increase, individuals will be able to make judgments and evaluate events in a multi-dimensional way by gaining critical thinking skills (Bahadır, 2018). In this context, educating individuals from an early age with an interdisciplinary perspective may contribute to the development of their critical thinking skills. This is because studies conducted with different disciplines will develop students' critical thinking (Wicklein & Schell, 1995).

In the tenth and eleventh development plans prepared by the T.R. Ministry of Development (2013) and the T.R. Presidency Strategy and Budget Office (2019), respectively, competencies, such as developing individuals' thinking skills, developing correct perception and ability to solve the problems encountered, have been determined as basic education objectives. In this context, as a research question, it was determined whether the Force and Energy unit developed by integrating STEM at the 7th-grade level had an effect on individuals' critical thinking skills.

2. Method

2.1. Research Model

In the quasi-experimental design, two of the available groups are determined and matched over various variables (Büyüköztürk et al., 2018). This research was a quasi-experimental design using pre-test and post-test. After the pre-test, the 7th grade Force and Energy Unit developed by the researcher with STEM integration was applied to the experimental group by another teacher for five weeks. Also, the control group was instructed by the same teacher.

2.2. Study Group

The process was carried out with the typical case sampling approach. For the implementation to be performed by a different teacher, a volunteer teacher was sought in a social communication network group consisting of about 60 science teachers in the Istanbul Kartal district and three volunteer teachers (one working in a private school and two working in public schools) were reached. Interviews were conducted with teachers working at public schools since the study primarily targeted students studying in public schools. This is because in a typical case sampling, the aim is to determine an average sample that is not extraordinary in the relevant universe (Büyüköztürk et al., 2018). Since one of the volunteer teachers was working in the public school, he did not approve the idea of doing a different teaching practice for the experimental group. Therefore, the other Science teacher working in the public school was determined as the practitioner and it was thought that the students studying at this school would represent the relevant universe better since the socio-economic levels of the families were at a medium level. In Turkey's STEM Education Report (2015), female students were stated to be less interested in STEM fields. Thus, the attention was especially paid to female students who have low interest in engineering (Ganesh et al., 2009; Knight & Cunningham, 2004). In the relevant sample school, male and female students were studying in separate classes. Two 7th classes (each consisting of 25 students) of female students who had equal academic achievements were determined. The experimental group students were randomly determined. To examine whether they had similar academic achievements, their grand point average scores of 6th grade were considered. First, normality analysis was performed.

Table 1. *Normality Test of Students' Grand Point Average Scores*

Variables	N	Skewness	Std.	Kurtosis	Std.
Group 1	25	-.256	.464	-.252	.902
Group 2	25	-.079	.464		.902

As is seen in Table 1, students showed a normal distribution. That the Skewness coefficient is between "-1 and +1" is an important step for a normal distribution (Büyüköztürk, 2017). Besides, the Kolmogorov-Smirnov test is performed if the number of students in the group is greater than 50, and if the number of students is less than 50, the Shapiro-Wilks test is used to examine whether the scores show a normal distribution (Büyüköztürk, 2017).

Since the number was less than 50, the Shapiro-Wilk test data in Table 2 were examined. Based on the results ($p > .05$), a t-test (one of the parametric tests) was used.

Table 2. *Normality Test of Students' Grand Point Average Scores*

Variables	Kolmogorov-Smirnov Z	p	Shapiro-Wilk Z	p
Group 1	.106	.200*	.974	.745
Group 2	.105	.200*	.968	.605

Also, the value of Levene's test, which is seen as a normality assumption, was investigated for variance equality. The data at the bottom of the sig. (2. tailed) value was presented in Table 3. Considering the data in Table 3 it was observed that there was no significant difference between the grand point average scores of 6th grade ($p > .05$). Thus, one of the two classes was determined as the experimental group and the other class was considered as the control group.

Table 3. *T-Test Results of Students' Grand Point Average Scores according to Groups*

Groups	N	$\bar{X}$	S	sd	t	p
Group1	25	75.05	8.13	48	-.976	.334
Group2	25	77.77	11.28			

2.3. Force and Energy Unit Development Process

During the process of developing the Force and Energy unit, MEB Science Curriculum (2018a), Middle School Mathematics Curriculum (2018b) and Technology and Design Lesson Curriculum (2018c) were examined in detail and common outcomes related to Force and Energy unit were determined. In the same period, the outcomes related to critical thinking skills in the Outcome-Centered STEM Applications published by the MEB General Directorate of Private Education Institutions (2019) were included in the developed unit.

The Force and Energy unit consisted of five sections, and scenarios were created in each section by establishing a connection with daily life. In the production process of these scenarios, the aim was for individuals to be inspired by nature while designing products. This is because many engineering products are designed with inspiration from nature. The first part of the developed unit included the concepts of mass and weight, and at the end of this section, individuals were asked to design a Hovercraft prototype. The second part involved the concept of physical work, and at the end of this part, individuals were required to design a Pull-Drop Work Vehicle prototype. The third part included the concepts of kinetic and gravitational potential energy. At the end of this chapter, individuals were asked to design a parachute prototype. In the fourth part, the concept of elastic potential energy was included, and in this chapter, individuals were required to design a Wind-Up Flying Vehicle prototype. In the last part, conservation of energy, kinetic energy loss by friction and air/water resistance concepts were included. At the end of this section, individuals were asked to design a Rocket prototype. In addition, in the design process of all products, limitations and success criteria were determined and individuals were asked to pay attention to these issues.

The engineering design process in 'Engineering is Elementary (2013) Program' was taken as the basis for the design of the products in the Force and Energy unit. In the Ask Questions, which is the first stage, it was aimed for individuals to obtain information about the product to be designed. In the Imagine stage, individuals tried to find solutions for product design using the brainstorming technique. In the Plan stage, it was aimed that individuals plan the actions to be carried out step by step, draw the product prototype in two dimensions and provide the necessary tools and materials. In the Create Product stage, individuals should follow the planned actions to turn the design into a product and determine whether the product works in accordance with the previously foreseen limitation and success criteria. In the Develop Product stage, individuals should pay attention to what works and what does not work efficiently in the developed product prototype. Also, individuals are required to make changes and retest them in order for the product to work more efficiently.

During the development of the Force and Energy unit, the opinions and suggestions of two field experts who researched STEM education were taken. In addition, the unit was examined by two Turkish language teachers to ensure the integrity of language and meaning. Then, the necessary arrangements were made.

2.4. Implementation Process

MEB (2018a) has determined five weeks for teaching the 7th grade Force and Energy unit in the Science Curriculum. In this context, the application period of the Force and Energy unit, which was developed with STEM Integration, was also set as the same period and applications were initiated with the experimental group students. During the implementation process, one week was allocated to each section, and students in the experimental group were asked to research outside of school as well. The out-of-school processes of the students gained significance in terms of supplying the necessary materials in the product design process and conducting research-development activities.

The 7th grade Science Textbook was used to teach students in the control group so that they could gain the outcomes underlined in the MEB Science Curriculum (2018a). The activities in the 7th Grade Science Textbook mostly consisted of activities aimed to learn the concepts in the Force and Energy unit, and the aim was to have students design a paper airplane at the end of the unit in an activity titled Science, Engineering and Entrepreneurship Applications. This design application is not sufficient for STEM education.

The applications submitted with the experimental and control groups were performed with the same teacher in similar classroom environments and for the same period. The experimental group was working on the Force and Energy unit developed with STEM Integration, while the control group was working on the Force and Energy unit in the Science Textbook.

Besides, the Force and Energy unit was piloted by the researcher with a different group of 7th-grade students. Thus, the necessary arrangements were made and the negativities that could be experienced during the implementation process were prevented.

2.5. Data Collection Tools

The Critical Thinking Scale (CTS) developed by Demir (2006a) was used to investigate whether there was a change in students' critical thinking skills during the research process. CTS consists of six sub-scales such as analysis, evaluation, inference, interpretation, explanation and self-regulation. While developing Analysis, Evaluation, and Inference sub-scales of CTS, Demir (2006b) performed test-retest with 201 students for three weeks, examined the double-serial correlation and Pearson correlation coefficients, and removed five items with low correlation. Considering the Pearson correlation values, he found .708 for the analysis sub-scale, .855 for the evaluation sub-scale, and .696 for the inference sub-scale. During the development of interpretation and explanation sub-scales, as the scales consisted of multiple-choice tests, he continued to work with the same students and examined the item difficulty and item discrimination indexes. Based on the data, he removed only one item from the explanation sub-scale and determined that the test items had moderate strength and a high level of discrimination. He also examined the KR-20 values to reveal the reliability coefficients and found .759 for the interpretation sub-scale and .768 for the explanation sub-scale. A test having .70 and above value is considered sufficient for the reliability of the test scores (Büyüköztürk, 2017). During the development of the self-regulation scale, which was designed as a Likert-type scale, he studied with the same students. The factor loads of the self-regulation sub-scale were examined and four items were removed from the scale due to the low factor loading of four items. The Cronbach's alpha value of the self-regulation sub-scale, which consists of twelve items in the final version, was also revealed as .91. Thus, the Critical Thinking Scale consisting of 56 items was developed.

3. Data Analysis

In this study, the change in individuals' critical thinking skills both within and between groups was analysed according to the scores obtained before and after the implementation.

3.1. Scores of the Critical Thinking Scale Obtained before Implementation

During the process of examining the critical thinking skills of students in the experimental and control group before the implementation, normality analysis was first performed.

As is seen in Table 4, a kurtosis value of ± 1.0 is considered perfect for most psychometric purposes, but a value between ± 2.0 can also be accepted depending on the specific implementations (George & Mallery, 2012).

Table 4. *Normality Test of Students' CTS Scores before the Implementation*

Pre-implementation of the Critical Thinking Scale	Groups	N	Skewness	Std.	Kurtosis	Std.
Analysis Sub-scale	Control Group	25	.048	.464	-.018	.902
	Experimental Group	25	-.897	.464	1.271	.902
Evaluation Sub-scale	Control Group	25	-.043	.464	-.810	.902
	Experimental Group	25	.014	.464	-1.891	.902
Inference Sub-scale	Control Group	25	-.448	.464	-.653	.902
	Experimental Group	25	-.240	.464	-1.356	.902
Interpretation Sub-scale	Control Group	25	-.916	.464	1.026	.902
	Experimental Group	25	-970	.464	1.641	.902
Description Sub-scale	Control Group	25	-1.286	.464	1.955	.902
	Experimental Group	25	-1.592	.464	2.401	.902
Self-Regulation Sub-scale	Control Group	25	-.688	.464	.420	.902
	Experimental Group	25	-.665	.464	1.186	.902
Critical Thinking Sub-scale	Control Group	25	-.270	.464	-.535	.902
	Experimental Group	25	-.365	.464	-.180	.902

Table 5. *Normality Test of Students' CTS Scores before the Implementation*

Variables	Kolmogorov-Smirnov Z	p	Shapiro-Wilk Z	p
Control Group	.094	.200	.974	.754
Experimental Group	.091	.200	.976	.800

According to the Kolmogorov-Smirnov test data in Table 5, it was decided that it would be appropriate to use an independent t-test, which is a parametric test, because of p> .05.

Table 6. *Pre-Implementation Independent T-Test Results of the Students' Scores according to Groups*

Scale	Groups	N	$\overline{X}$	S	sd	t	p
Analysis Sub-scale	Control Group	25	6.4000	1.04083	48	-.244	.808
	Experimental Group	25	6.4800	1.26227			
Evaluation Sub-scale	Control Group	25	6.4000	1.84842	48	.563	.576
	Experimental Group	25	6.0400	2.60576			
Inference Sub-scale	Control Group	25	5.2400	1.92094	48	.445	.658
	Experimental Group	25	5.0000	1.89297			
Interpretation Sub-scale	Control Group	25	8.0000	1.77951	48	-.609	.546
	Experimental Group	25	8.2800	1.45831			
Description Sub-scale	Control Group	25	7.4400	1.19304	48	-.500	.619
	Experimental Group	25	7.6400	1.60416			
Self-Regulation Sub-scale	Control Group	25	15.5200	2.55147	48	-1.716	.093
	Experimental Group	25	16.8800	3.03205			
Critical Thinking Scale	Control Group	25	49.0000	5.93015	48	-.755	.454
	Experimental Group	25	50.3200	6.42080			

Table 6 displays that there was no significant difference between the control and experimental groups regarding critical thinking skills (p> .05). Thus, it can be said that students of both groups had close critical thinking skills before the implementation.

3.2. Scores Received from the Critical Thinking Scale after the Implementation

During the process of examining the critical thinking skills of the experimental and control group after the implementation, normality analysis was first performed.

Table 7. *Normality Test of Students' CTS Scores after the Implementation*

Post-implementation of the Critical Thinking Scale	Groups	N	Skewness	Std.	Kurtosis	Std.
Analysis Sub-scale	Control Group	25	.193	.464	-1.222	.902
	Experimental Group	25	-1.104	.464	2.214	.902
Evaluation Sub-scale	Control Group	25	-.355	.464	-1.270	.902
	Experimental Group	25	-.600	.464	-.555	.902
Inference Sub-scale	Control Group	25	.195	.464	-.679	.902
	Experimental Group	25	-.847	.464	1.707	.902
Interpretation Sub-scale	Control Group	25	-1.641	.464	4.180	.902
	Experimental Group	25	-2.127	.464	3.539	.902
Description Sub-scale	Control Group	25	-1.454	.464	2.114	.902
	Experimental Group	25	*		*	
Self-Regulation Sub-scale	Control Group	25	-.446	.464	-.968	.902
	Experimental Group	25	.256	.464	-1.167	.902
Critical Thinking Scale	Control Group	25	-.955	.464	.192	.902
	Experimental Group	25	-.920	.464	.989	.902

*Since the whole students in the experimental group answered all the questions in the Explanation sub-scale correctly, there was no skewness and kurtosis value.

Considering the whole set of Critical Thinking Scale, the fact that the coefficient of skewness was between "-1 and +1" indicates that it is a normal distribution (Büyüköztürk, 2017). At the same time, since the number of students in the group was 50, the Kolmogorov-Smirnov test was examined to see if it showed a normal distribution (Büyüköztürk, 2017).

Table 8. *Normality Test of Students' CTS Scores after the Implementation*

Variables	Kolmogorov-Smirnov Z	P	Shapiro-Wilk Z	P
Control Group	.155	.122	.904	.023
Experimental Group	.108	.200	.925	.065

Considering the Kolmogorov-Smirnov test data in Table 8, it was decided that it would be appropriate to use an independent t-test, which is a parametric test, because of $p > .05$.

Table 9. *Post-Implementation Independent T-Test Results of the Students' Scores according to Groups*

Scale	Groups	N	$\bar{X}$	S	sd	t	p
Analysis Sub-scale	Control Group	25	6.6000	1.0408	48	-.376	.708
	Experimental Group	25	6.7200	1.2083			
Evaluation Sub-scale	Control Group	25	6.6400	1.7530	48	-.388	.699
	Experimental Group	25	6.8400	1.8859			
Inference Sub-scale	Control Group	25	5.1600	1.4910	48	-.379	.706
	Experimental Group	25	5.3200	1.4922			
Interpretation Sub-scale	Control Group	25	8.3200	1.8645	48	-3.566	.001
	Experimental Group	25	9.7200	.61373			
Description Sub-scale	Control Group	25	7.4800	1.8284	48	-4.156	.000
	Experimental Group	25	9.0000	.00000			
Self-Regulation Sub-scale	Control Group	25	16.5600	2.6153	48	-.244	.809
	Experimental Group	25	16.7600	3.1659			
Critical Thinking Scale	Control Group	25	50.7600	6.1932	48	-2.122	.039
	Experimental Group	25	54,3600	5,7942			

Table 9 presents that there was a significant difference ($p < .05$) between the overall scores of the Critical Thinking Scale in favour of the experimental group. Besides, there was a significant difference ($p < .05$) between the scores obtained from the Interpretation and Explanation sub-scales of the Critical Thinking Scale in favour of the experimental group.

3.3. Scores of the Control Group Received from the Critical Thinking Scale before and after the Implementation

While examining the changes in the critical thinking skills of the control group before and after the implementation, normality analysis was first performed. The normality analysis was examined by considering the difference between the pre-implementation and post-implementation CTS scores of the control group.

Table 10. *Normality Test of CTS Scores of Students in Control Group before and after the Implementation*

Critical Thinking Scale	Group	N	Skewness	Std.	Kurtosis	Std.
Difference of Analysis Scores	Control Group	25	-.119	.464	-.277	.902
Difference of Evaluation Scores	Control Group	25	-.099	.464	-.594	.902
Difference of Inference Scores	Control Group	25	.016	.464	-.280	.902
Difference of Interpretation Scores	Control Group	25	.636	.464	3.871	.902
Difference of Explanation Scores	Control Group	25	-.824	.464	2.305	.902
Difference of Self-regulation Scores	Control Group	25	-.337	.464	-.080	.902
Difference of Critical Thinking Scores	Control Group	25	-.086	.464	-.281	.902

When Kurtosis and Skewness values are between -1.5 and +1.5, it is accepted to be normal distribution (Tabachnick & Fidell, 2013). In the same vein, a kurtosis value of ± 1.0 is considered perfect for most psychometric purposes, but a value between ± 2.0 can be accepted depending on a specific implementation (George & Mallery, 2012). According to Table 10, the scores of the control group obtained before and after the implementation showed a normal distribution. Therefore, a dependent t-test was applied to examine whether there was a significant difference between the scores.

Table 11. *Pre- and Post-Implementation Dependent T-Test Results of the Students' Scores in Control Group*

Critical Thinking Scale	Control Groups	N	$\overline{X}$	S	sd	t	p
Analysis Scores	Pre-Test	25	6.4000	1.04083	24	-.679	.503
	Post-Test	25	6.6000	1.04083			
Evaluation Scores	Pre-Test	25	6.4000	1.84842	24	-.586	.563
	Post-Test	25	6.6400	1.75309			
Inference Scores	Pre-Test	25	5.2400	1.92094	24	.175	.863
	Post-Test	25	5.1600	1.49108			
Interpretation Scores	Pre-Test	25	8.0000	1.77951	24	-.736	.469
	Post-Test	25	8.3200	1.86458			
Explanation Scores	Pre-Test	25	7.4400	1.19304	24	-.108	.915
	Post-Test	25	7.4800	1.82848			
Self-Regulation Scores	Pre-Test	25	15.5200	2.55147	24	-1.87	.073
	Post-Test	25	16.5600	2.61534			
Critical Thinking Scores	Pre-Test	25	49.0000	5.93015	24	-1.45	.160
	Post-Test	25	50.7600	6.19328			

Table 11 indicates that there was no significant difference ($p > .05$) in the critical thinking skills of students in the control group. This can be interpreted that the students in the control group had similar critical thinking skills before and after the implementation.

3.4. Scores of the Experimental Group Received from the Critical Thinking Scale before and after the Implementation

While examining the experimental group students' critical thinking skills before and after the implementation, normality analysis was first performed. The normality analysis was examined by considering the difference between the pre-implementation and post-implementation CTS scores of the experimental group.

When Kurtosis and Skewness values are between -1.5 and +1.5, it is accepted to be a normal distribution (Tabachnick & Fidell, 2013). At the same time, a kurtosis value of ± 1.0 is considered perfect for most psychometric purposes, but a value between ± 2.0 can be accepted depending on a specific implementation (George & Mallery, 2012). According to Table 11, the scores of the experimental group obtained before and after the implementation showed a normal distribution. Therefore, a dependent t-test was applied to examine whether there was a significant difference between the scores.

Table 12. Normality Test of CTS Scores of Students in Experimental Group before and after the Implementation

Critical Thinking Scale	Group	N	Skewness	Std.	Kurtosis	Std.
Difference of Analysis Scores	Experimental Group	25	,666	,464	-,311	,902
Difference of Evaluation Scores	Experimental Group	25	,417	,464	,028	,902
Difference of Inference Scores	Experimental Group	25	-,171	,464	-,548	,902
Difference of Interpretation Scores	Experimental Group	25	1,085	,464	1,214	,902
Difference of Explanation Scores	Experimental Group	25	1,592	,464	2,401	,902
Difference of Self-Regulation Scores	Experimental Group	25	-,107	,464	-,790	,902
Difference of Critical Thinking Scores	Experimental Group	25	,514	,464	-,632	,902

Table 13. *Pre- and Post-Implementation Dependent T-Test Results of the Students' Scores in Experimental Group*

Critical Thinking Scale	Experimental Groups	N	$\overline{X}$	S	sd	t	p
Analysis Scores	Pre-Test	25	6.4800	1.2622	24	-1.238	.228
	Post-Test	25	6.7200	1.2083			
Evaluation Scores	Pre-Test	25	6.0400	2.6057	24	-2.219	.036
	Post-Test	25	6.8400	1.8859			
Inference Scores	Pre-Test	25	5.0000	1.8929	24	-.927	.363
	Post-Test	25	5.3200	1.4922			
Interpretation Scores	Pre-Test	25	8.2800	1.4583	24	-5.566	.000
	Post-Test	25	9.7200	.6137			
Explanation Scores	Pre-Test	25	7.6400	1.6041	24	-4.239	.000
	Post-Test	25	9.0000	.0000			
Self-Regulation Scores	Pre-Test	25	16.8800	3.0320	24	.188	.853
	Post-Test	25	16.7600	3.1659			
Critical Thinking Scores	Pre-Test	25	50.3200	6.4208	24	-4.858	.000
	Post-Test	25	54.3600	5.7942			

As is seen in Table 13, there was a significant difference ($p< .05$) in the critical thinking skills of the students in the experimental group. Thus, it can be stated that there was a difference between the critical thinking skills of the students in the experimental group before and after the implementation. Also, a significant difference ($p< .05$) was found between the scores obtained from the Evaluation, Interpretation and Explanation sub-scales before and after the implementation.

4. Discussion, Conclusion and Recommendations

This study examined the effects of the Force and Energy Unit (in which STEM was integrated) on the critical thinking skills of 7th-grade students in the Science Course. Before the implementation, the data obtained from CTS were examined to investigate whether there was a significant difference between the experimental and control groups regarding critical thinking skills. No significant difference was found between groups ($p> .05$). After a five-week implementation, data were reanalysed, and a significant difference was observed in favour of the experimental group ($p< .05$). When the scores obtained from the sub-scales (Interpretation and Explanation) were compared, a significant difference was found in favour of the experimental group ($p> .05$). The scores that participants got before and after the CTS were examined to identify the changes that occurred during the process. Accordingly, while there was a significant difference in the experimental group ($p>.05$), there was no significant difference in the control group ($p<.05$). Besides, a significant difference was found ($p< .05$) between the scores obtained by the experimental group from the Evaluation, Interpretation and Explanation sub-scales before and after the implementation. The experimental group students' handling of the claims and arguments in the information sources in the process of acquiring theoretical information about product design may contribute to developing assessment skills. Also, while solving the problems presented in the scenarios, students' understanding and describing the problem and attaching significance to revealing the most ideal design may improve their interpretation skills. Besides, Individuals may develop their explanation skills by presenting arguments for product design to impose their ideas on their friends, following the engineering design process and a certain procedure, and expressing the results by looking at how effectively the products they created work or did not work. To improve the analysis, inference and self-regulation skills of individuals, it may be effective to introduce new product designs. To achieve this situation, larger time is needed in the implementation process.

These results coincide with the results of Rehmat (2015), who examined the effect of problem-based STEM activities on critical thinking skills of primary school students. In his study with 7th-grade students, Topsakal (2018) determined that individuals' critical thinking dispositions increased with problem-based STEM activities. In their studies with 8th-grade students by integrating the disciplines of Mathematics and Science, Elliott et al. (2001) found that an interdisciplinary approach is effective in the development of individuals' critical thinking skills. This research finding indicates that individuals who receive STEM education have improved their critical thinking skills. When the literature is examined, there is a dearth of studies on STEM education and the development of critical thinking skills. In STEM education, some situations (e.g., in-group discussions during the research and prototype development process for the solution of the problem, and the evaluation of the draft prototypes that individuals put forward individually during the modelling process) can contribute to the development of the experimental group's critical thinking skills. In their study with 6th-grade students, Bakırcı and Çepni (2016) stated that activities, such as in-group discussions and peer-assessment, are among the factors that enable the development of critical thinking skills. Based on these data, it can be said that STEM education improves critical thinking skills.

In STEM education, while individuals design products to solve related problems, they benefit from different disciplines simultaneously. This will support the development of critical thinking skills by contributing to individuals' multi-directional thinking over time. In this process, individuals can quickly turn to the prototype of the product they are designing without necessary scientific research (Ercan & Şahin, 2015). If teachers can manage this process, which is considered significant for the development of individuals' critical thinking skills, a meaningful change may occur in individuals. Besides, increasing the number of units with STEM integration for all students will contribute to developing their critical thinking skills.

5. References

Akgündüz, D., Aydeniz, M., Çakmakçı, G., Çavaş, Bület, Çorlu, M. S., & Öner, T. (2015). *STEM eğitimi Türkiye raporu: "Günümüz modası mı yoksa gereksinim mi?"*. İstanbul Aydın Üniversitesi *STEM Merkezi*.

Bahadır, E. (2018). GEMS ve matematik eğitimi *I. Uluslararası Eğitimde Yeni Arayışlar Kongresi* Bildiri Özetleri Kitabı, 149-152.

Bahar, M., Yener, D., Yılmaz M. & Emen, H., Gürer, F. (2018). 2018 Fen bilimleri öğretim programı kazanımlarındaki değişimler ve fen teknoloji matematik mühendislik (STEM) entegrasyonu. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi, 18* (2), 702-735.

Bakırcı, H. & Çepni, S. (2016). Ortak bilgi yapılandırma modelinin ortaokul altıncı sınıf öğrencilerinin eleştirel düşünme becerilerine etkisi: Işık ve ses ünitesi Örneği. *İnönü Üniversitesi Eğitim Fakültesi Dergisi, 17*(3), 185-202. doi: 10.17679/inuefd.17308627

Büyüköztürk, Ş (2017). *Sosyal bilimler için veri analizi el kitabı* (23. Baskı). Pegem Akademi Yayınları.

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö.E., Karadeniz, Ş. & Demirel, F. (2018). *Bilimsel araştırma yöntemleri* (25. Baskı). Pegem Akademi Yayınları.

Çetin, A. (2020). Examining project-based STEM training in a primary school. *International Online Journal of Education and Teaching (IOJET), 7*(3). 811- 825.

Çınar, S., Pırasa, N., & Sadoğlu, G. P. (2016). Views of science and mathematics preservice Teachers Regarding STEM. *Universal Journal of Educational Research*, *4*(6), 1479-1487.

Demir, M. K. (2006a). İlköğretim dördüncü ve beşinci sinif öğrencilerinin sosyal bilgiler derslerinde eleştirel düşünme düzeylerinin çeşitli değişkenler açisindan incelenmesi, *Gazi Eğitim Fakültesi Dergisi, 26*(3),155-169.

Demir, M. K. (2006b). *İlköğretim dördüncü ve beşinci sinif öğrencilerinin sosyal bilgiler derslerinde eleştirel düşünme düzeylerinin çeşitli değişkenler açisindan incelenmesi* [Yayınlanmamış doktora tezi]. Gazi Üniversitesi.

Elliott, B., Oty, K., McArthur, J. & Clark, B. (2001). The effect of an interdisciplinary algebra/science course on students‟ problem solving skills, critical thinking skills and attitudes towards mathematics. *International Journal of Mathematical Education in Science and Technology, 32*(6), 811–816.

Engineering is Elementary (2013), The Engineering Design Process. Retrieved September, 04, 2018, from http://www.eie.org/overview/engineering-design-process

Ercan, S & Şahin, F. (2015). Fen eğitiminde mühendislik uygulamalarinin kullanimi: Tasarim temelli fen eğitiminin öğrencilerin akademik başarilari üzerine etkisi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi, 9*(1), 128- 164.

Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction* - Executive Summary - The Delphi Report. Millbrae, CA: The California Academic Pres. Retrieved from https://www.qcc.cuny.edu/socialsciences/ppecorino/CT-Expert-Report.pdf

Ganesh T., Thieken J., Elser M., Baker, D., Krause, S., Roberts, C., Kurpius-Robinson, S., Middleton, J. & Golden, J. (2009). *Eliciting underserved middle-school youths' notions of engineers: Draw an engineer. Paper presented at American Society of Engineering Education.* Annual Conference & Exposition; Austin, TX. Retrieved May, 10, 2020. https://peer.asee.org/5796

George, D., & Mallery, M. (2010). *SPSS for windows step by step: A simple guide and reference*, 17.0 update (10a ed.). Pearson.

Gülhan, F. &Şahin, F. (2016). Fen-teknoloji-mühendislik-matematik entegrasyonunun (STEM) 5. sınıf öğrencilerinin bu alanlarla ilgili algı ve tutumlarına etkisi. *International Journal of Human Sciences, 13*(1). 602-620. doi:10.14687/ijhs.v13i1.3447

Kökdemir, D. (2003). *Belirsizlik durumlarinda karar verme ve problem çözme* (Yayınlanmamış Doktora Tezi]. Ankara Üniversitesi Sosyal Bilimler Enstitüsü.

Knight, M. & Cunningham, C. M. (2004). *Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering.* Retrieved May, 10, 2020, from https://www.researchgate.net/publication/237337105

MEB, (2016). *STEM Eğitimi Raporu*. Ankara: Yenilik ve Eğitim Teknolojileri Genel Müdürlüğü. Retrieved from http://yegitek.meb.gov.tr/stem_egitimi_raporu.pdf

MEB, (2018a). *Fen bilimleri dersi öğretim programı, (İlkokul ve Ortaokul 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Talim ve Terbiye Kurulu Başkanlığı.

MEB, (2018b). *Matematik dersi öğretim programı (İlkokul ve Ortaokul 1, 2, 3, 4, 5, 6, 7 ve 8. Sınıflar)*. Talim ve Terbiye Kurulu Başkanlığı.

MEB, (2018c). *Bilişim teknolojileri ve yazılım dersi öğretim programı, (Ortaokul 5 ve 6. Sınıflar).* Talim ve Terbiye Kurulu Başkanlığı.

MEB, (2018d). *Teknoloji ve tasarım dersi öğretim programı (Ortaokul 7 ve 8. Sınıflar).* Talim ve Terbiye Kurulu Başkanlığı.

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: The National Academies Press.

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Özbilen, A. G. (2018). Stem eğitimine yönelik öğretmen görüşleri ve farkındalıkları. *Scientific Educational Studies, 2*(1), 1-21.

Rehmat, A. P. (2015). *Engineering the path to higher-order thinking in elementary education: A problem-based learning approach for STEM integration* [Doctoral dissertation]. University of Nevada.

Şenşekerci E., & Bilgin A. (2008), Eleştirel düşünme ve öğretimi, *U.Ü. Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi, 14*(1), 15-41.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Pearson.

Tezcan, G. (2019). *Ortaokul fen bilimleri ders kitaplarinda yer alan etkinliklerin bilim, teknoloji, mühendislik ve matematik yaklaşimina uygunluğunun incelenmesi ve öğretmen görüşleri* [Yayınlanmamış yüksek lisans tezi]. Van Yüzüncü Yıl Üniversitesi.

Topsakal İ. (2018). *Probleme dayalı STEM eğitiminin öğrencilerin öğrenme iklimlerine, eleştirel düşünme eğilimlerine ve problem çözme becerilerine yönelik algilarina etkisinin araştirilmasi* [Yayımlanmamış üksek lisans tezi]. Erzincan Binali Yıldırım Üniversitesi.

Tozlu, İ., Gülseven, E. & Tüysüz, M. (2019). FeTeMM eğitimine yönelik etkinlik uygulaması: kuvvet ve enerji örneği, *YYÜ Eğitim Fakültesi Dergisi (YYU Journal of Education Faculty), 16*(1), 869-896.

TÜSİAD (2014). STEM (Science, Technology, Engineering and Mathematics, Fen, Teknoloji, Mühendislik, Matematik) alanında eğitim almış işgücüne yönelik talep ve beklentiler araştırması. TUSİAD.

T.R. Ministry of Development [T.C. Kalkınma Bakanlığı] (2013), Onuncu Kalkınma Planı. Retrieved October, 04, 2020, from https://www.sbb.gov.tr/wp-content/uploads/2018/11/Onuncu-Kalk%C4%B1nma-Plan%C4%B1-2014-2018.pdf

T.R. Presidency Strategy and Budget Office [T.C. Cumhurbaşkanlığı Strateji ve Bütçe Başkanlığı] (2019), Onbirinci Kalkınma Kalkınma Planı. Retrieved October, 04, 2020, from https://www.sbb.gov.tr/wp-content/uploads/2019/11/ON_BIRINCI_KALKINMA-PLANI_2019-2023.pdf

Wagner, T. (2008). Rigor redefined. *Educational Leadership*, *66*(2), 20-24.

Wicklein R. C. & Schell J. W. (Spring 1995). Case studies of multidisciplinary approaches to integrating mathematics, science and technology education. *Journal of Technology Education. 6* (2), 59-76. Retrieved August, 07, 2020, from https://scholar.lib.vt.edu/ejournals/JTE/v6n2/wicklein.jte-v6n2.html

Yıldırım, B. & Altun, Y. (2015). STEM eğitim ve mühendislik uygulamalarının fen bilgisi laboratuvar dersindeki etkilerinin incelenmesi. *El-Cezerî Fen ve Mühendislik Dergisi, 2*(2), 28- 40.