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STEM Education Effect on Inquiry Perception and Engineering Knowledge

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Despite the adoption of modern educational approaches such as activity-based, laboratory-based, technology enhanced science education, it is known that in most cases, students have difficulties in achieving desired learning goals such as developing inquiry skills and engineering knowledge. The efforts of science educators to ensure that students reach the desired learning goals have led to the development of new educational approaches. It is then necessary to put the emerging educational approaches into practice, to determine their effects in practice, and to determine the level of achieved learning goals. Therefore, the study intends to examine the effect of Science, Technology, Engineering and Mathematics (STEM) supported science teaching on the perception of inquiry learning skills and engineering knowledge level of 8th graders regarding Basic Machines unit. Quasi experimental research design was adopted. The study was conducted with 8th grade students. The participant students were recruited through easily accessible sampling method. This study was implemented during five weeks. The Inquiry Learning Level Perception Scale (ILSPS) and the Engineering Knowledge Level Scale (EKLS) were data collection tools. The data obtained revealed that STEM supported science teaching was effective on 8th graders inquiry learning skill perception and engineering knowledge levels. It is recommended to carry out comprehensive studies to reveal the effect of STEM-supported science teaching on students' design skills in the 21st century.

Introduction

The rapid changes in science and technology affect the economic policies of the countries as well as their education systems. Through developments in technology, it has become important to train qualified workforce in various fields. In this context, the idea has become to more accepted as increasing productivity and individual inquiry (Bowen & Shume,

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2020). Within the scope of these developments, countries had to change their education policies for having the desired position in science and technology. Many countries have inclined to educational approaches that will provide individuals with 21st century skills in order to train qualified workforce. This situation has led to the emergence of new educational approaches. One of these educational approaches can be said to be STEM education (Purzer, Goldstein, Adams, Xie & Nourian, 2015).

STEM is an educational approach enable learners to gain problem solving and 21st century skills through multidisciplinary understanding and engineering design (Bybee, 2010). As can be understood from this definition, this educational approach is seen to be an interdisciplinary approach. The aim of STEM education is developing a science-literate society, as well as to develop a workforce that understands STEM (Dugger, 2010). With the advancement of technology, it is among the economic and cultural goals of the countries to train qualified employees in the profession groups in STEM (Kennedy & Odell, 2014).

STEM education has features such as being student-centered, supporting students' high-level thinking skills, providing students with problem-solving skills, and enabling students to keep the acquired information longer in their mind (Siew & Ambo, 2020). One of the most important skills among the 21st century skills is the inquiry learning skill. STEM education based on real-life applications provides students with experiential and collaborative learning opportunities, encourages students to gain experimentally scientific principles, problem solving, inquiry and inquiry learning skills (National Science and Technology Council [NSTC], 2013). STEM based science teaching contributes to students' questioning of the problems that they encounter in daily life and producing solutions. It is among the aims of this education that students can find solutions to the problems that they encounter outside of school. With STEM education, the individual gains inquiry learning skills and produces solutions to daily life problems. From this point of view, the impact of science teaching assisted through STEM education on eighth grade students' inquiry learning skills makes this study important (Hu, Chiu & Chiou, 2019).

It is recommended that children from the early ages should gain an interdisciplinary perspective through mathematics, technology, engineering, and art in addition to the science courses, and gain skills in problem solving, questioning, conducting research and product development (Ministry of National Education [MoNE], 2016). The engineering design skills includes creating products and developing strategies for adding value to the created products by bringing students to the level of innovation with an interdisciplinary perspective on problem solving and combining the learned knowledge and skills in science courses through mathematics, technology and engineering (MoNE, 2018a).

Integration of STEM education with existing education system is considered to be in the economic sense of contribution to Turkey (Corlu & Capraro Capraro, 2014). In order to improve the innovation capacity of Turkey, there is a strong need of highly qualified STEM workforce. In this context, Turkey has prepared Vision 2023 and the 2014 Ministry of National Education (MoNE) strategic plan. Similarly, Turkish Industry and Business Association (TUSIAD) announced a responsibility report with an emphasize on a need to build up a strategy for STEM education so that students gain 21st century skills and grow up as questioning and analytical thinking individuals (TUSIAD, 2017). Therefore, TUSIAD (2017) stated that STEM is a key feature in global competition, attention should be paid to STEM awareness, and this will increase the quality of education as a result. MoNE has not remained indifferent to the reflection of rapidly changing science and technology on today's educational approaches, and in its 2023 Education vision, several studies were envisioned for students to gain 21st century skills such as design-skill workshops (MoNE, 2018b).

Design-skill workshops is designed as workshops associated with professions that attach importance to the use of psychomotor skills of students in line with a common goal at K12 levels. In these workshops, students will enjoy designing, making, and producing rather than knowing. Through the workshops, it is aimed for the student to get to know himself, his profession, and his environment. These workshops can be organized as concrete spaces so that students can acquire 21st century skills (MoNE, 2018). With the establishment of design-skill workshops and the inclusion of STEM education in its curricula, MoNE aims to raise students as producers and individuals with 21st century skills by not being indifferent to the educational approaches of our age.

The engineering design process acts as a catalyst that carries the four main disciplines of STEM in the same environment. In this process, students gain a holistic perspective that includes other disciplines while solving problems (Benek & Akçay, 2022). In addition, it is possible to consolidate science education through the engineering design process, since it is linked to STEM disciplines (Bybee, 2010). Students become open to new learning by gaining experience such as scientific inquiry, scientific research, and setting up experiments in the engineering design process, and these points play an active role for meaningful learning. In addition, students' experience of processes such as questioning and learning by doing-living are among the points where the science teaching and engineering design process intersect with each other (Luo, So, Li, & Yao, 2021). The bridge between producing solutions to problems for both disciplines initiate the process of inquiry, and a cognitive mobility is experienced in the student for this (Purzer et al., 2015). Scientific research process in science continues with a question and the hypothesis, data and analysis/synthesis steps that will answer this question. The engineering process, on the other hand, results in a problem, steps that will bring a solution to this problem and presenting a prototype (National Research Council [NRC], 2012).

Most of today's educational approaches aim to enable students to experience daily life problems and to gain the skills of generating solutions to these problems. In addition, it is emphasized that students gain inquiry learning skills and become science and technology literate and are raised as individuals who produce in changing living conditions by gaining engineering skills. In line with this and similar economic and social purposes, STEM education was included in the Science Curriculum (Kırıcı & Bakırcı, 2021). With the inclusion of STEM education in the program, it became apparent that teachers should do their lessons according to this educational approach while teaching science. Thus, the conducted study is considered to be important to present an exemplary application for this understanding of education by applying STEM-supported science teaching in the teaching of "Basic Machines" unit and creating a learning environment based on this application. In addition, it is also considered that this study is assumed to make contributions to the research focusing on students' acquisition of 21st century skills.

Limited number of studies was found on STEM activities related to the "Basic Machines" unit within the scope of the science course (Sinatra, Mukhopadhyay, Allbright, Marsh & Polikoff, 2017). What makes this study different from other studies is the development of the activities in the "Basic Machines" unit and investigating its effect on the student's perception of inquiry learning skills and engineering knowledge. In this context, the study is assumed to contribute to new studies and developed STEM activities through the study for the Basic Machines unit will provide resources as teaching material for science teachers. In the same vein, it is important in terms of being an exemplary guide material for the development of STEM activities in other units of the science course for new researchers. Finally, it is believed that these guide teaching materials will play an important role in providing eighth grade students with 21st century skills. Therefore, the main problem of this study is “Does STEM supported science education have an effect on 8th grade students’ perception of inquiry learning skills and engineering knowledge within the scope of the unit of Basic Machines?”. In parallel, the sub-problems are defined with respect to inquiry learning skills and engineering knowledge.

(1) 1. Do the practices in experimental and comparison groups have an effect on eighth grade students’ perceptions of inquiry learning skills?
(2) 2. Do the practices conducted in the groups have an impact on the engineering knowledge level of 8th graders?

Method

Research Design

To examine the impact of STEM implementation, the researchers followed the quasi-experimental design. This design is preferred if there is one or more of the groups that were previously formed in a way other than random distribution. But the formed groups are randomly assigned as experimental and comparison groups, but care is taken to ensure that the participants are as similar as possible (Çepni, 2011). Since the implemented teaching on 8th graders’ inquiry learning perception and engineering knowledge levels was investigated, the quasi-experimental design was adopted. Two of the classes previously created by the school administration were included in the study. There are five eighth grade classes in the implementation school. To identify the classes required for the research, one of them assigned as the experimental while the other as the comparison group, by considering previous year science exam score averages of the students.

Research Group

All students included into the research group were at 8th grade in the same secondary school in Antalya. The research group was included 37 students. The comparison group comprised 19 students while the experimental group consisted of 18 students. Easily accessible sampling was preferred to determine the research group. Variables such as the researcher working at the school where the application was performed, the experiment, allowing the comparison of the comparison group and being economical were effective in the selection of this sample. Therefore, this sample provides speed and practicality to the research (Çepni, 2011).

Data Collection Tools

Inquiry Learning Skills Perception Scale (ILSPS)

ILSPS was used in the study which was developed by Balım and Taşkoyan (2007). The scale is 5- point Likert type including 23 items. The validity analysis conducted by Balım and Taşkoyan (2007) revealed that there were 23 items listed in three dimensions. Dimensions are named as "Positive Perception", "Negative Perception" and "Inquiring the truth perception". While there are 9 items in the "Positive Perception" dimension, there are seven items in the "Negative Perception" and "Inquiring the truth perception" dimensions. The reliability value was 0.84 which is calculated in terms of Cronbach Alpha. The reliability coefficient was found for the "Positive Perception", as 0.67, for the "Negative Perception" as 0.73 and for the

"Inquiring the truth perception" as 0.71 (Balım & Taşkoyan, 2007). Before the implementation, the researcher of this study applied ILPSP to 100 students of eighth grade for the reliability issues. Positive perceptions Cronbach Alpha coefficient was 0.69, negative perceptions Cronbach Alpha coefficient was 0.72, perceptions of questioning accuracy were determined as Cronbach Alpha coefficient 0.75. In this way, it was concluded that the scale could be used for the study.

Engineering Knowledge Level Scale (EKLS)

The Engineering Knowledge Level Scale (EKLS) developed by Harwell, Moreno, Phillips, Guzey, Moore & Roehrig (2015). The Turkish adaptation of the EKLS was realized by Aydın, Saka, and Guzey (2018). Although the scale was included 15 items, it is one-dimensional and multiple choice. It was created with four options considering the student level. The reasons for preparing the scale as multiple choice are the fact that the teacher can make the assessment in a short time for crowded classes and the cost is cheap. The measuring tool aims to measure the definition of engineering, how engineers work, and engineering design processes (Aydın, Saka, & Guzey, 2018). According to Guttman Split-Half reliability analysis results, the reliability coefficient for the measuring tool was determined as 0.71. Three field experts were consulted and the compliance with the field was checked for the validity of the EKLS content in the trial form translated into Turkish. While determining the experts, it was taken into account that they had studies on scale development and that they were a faculty member in the department of measurement and evaluation. After the field experts examined the measurement tools, corrections were made in the measurement tools in line with the suggestions and the measurement tools were finalized. A linguistic equivalence analysis was proceeded to investigate the consistency between the Turkish and English scale format, which were obtained after the necessary arrangements.

The researcher recalculated the EKLS reliability for the study group. It was primarily implemented to 100 students from eighth grader. The obtained scores were listed in descending order, 27% of the high scorers were identified as the upper group. While 27% of the low scorers were defined as the lower group. The equivalent half-way method was used to test the reliability of EKLS (Kalaycı, 2005). With the help of this method, the inter-half correlation coefficient of the test was found to be 0.78, and the reliability of the whole test was determined as 0.87. Since this value approaches one, it is considered to be a reliable value (Büyüköztürk, 2017).

Implementation Process

The implementation period took place in 5 weeks (20 lesson hours). The experimental group had the implementation in the design workshop while the comparison group in the classroom. The implementation was proceeded in accordance with STEM supported 5E model in the experimental group while comparison group had 5E learning model. All the implementation processes were conducted by the same researcher.

Before the research, STEM activities were developed in accordance with the Basic Machines unit objectives of the science curricula. Various activities were carried out by making use of http://www.morpakampus.com and http://www.eba.gov.tr websites suitable for the subject headings for learners to enable better understanding of the issues possible to have difficulties and to support the technology discipline. Below is a screenshot of the activities used on these web sites.

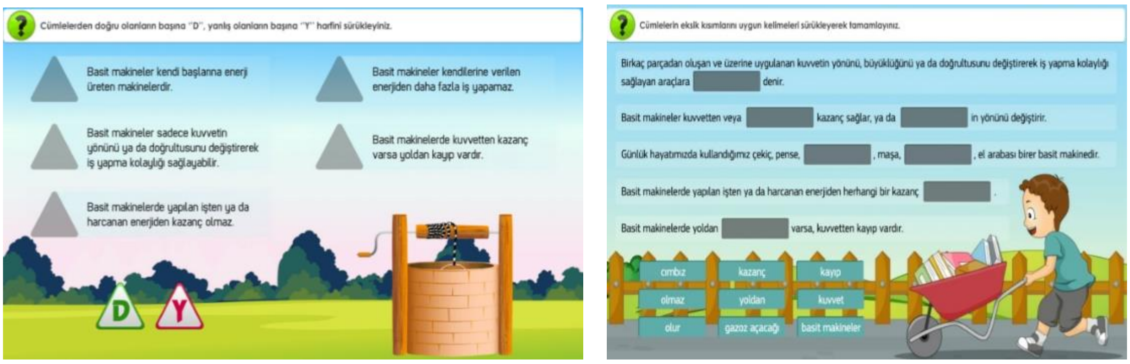

Figure 1 Screenshots of the activities

The activities are arranged in a way that enables the participants to design the lever, pulleys, inclined plane, spinning wheel and ferries wheel (compound machine) materials to support the engineering discipline with simple materials given to them in accordance with the unit topics.

Implementation in the Experimental Group

The first topic of the first week is leverage. The teacher entered the classroom with the prepared activities for STEM education and the materials to be used in the activity. The teacher divided the class into five groups of four within the scope of the collaborative learning method. The teacher asked students to read the problem situation on the activity sheet with their group mates.

Problem Situation: Reading the words of Archimedes "Give me a leverage, let me move the world" from the science textbook, Adem decides to build his own lever in the garden to understand how to achieve this. What should Adem, who has a 50 cm long board, do to lift 0.05 kg tennis ball and 0.650 kg basketball?

Figure 2 Archimedes leverage to lift the world

The students who examined the problem situation were asked to address the first instruction "1. What could be the solution / solutions to solve the problem situation of the mechanism you will design?" by discussing with their group. They were asked to produce an answer by discussing with their group friends. At this stage, the entrance phase of the 5E learning model was taken into consideration and the science discipline was used. The aim here is to encounter the students with a problem situation from daily life, increase their motivation by attracting their attention, and enable them to provide solutions for the problem situation.

In the exploration phase, the teacher asked students to write down the information they found in the activity sheet, with the instruction "2. Discuss and write down what kind of information you need for the mechanism you will design" with your group.

In the explanation phase, the teacher started to teach the subject of leverage in accordance with the Science Curriculum, based on the knowledge acquired by the students. While the teacher was teaching the subject, he also resorted to the smart board in the classroom, which is the application of the Ministry of Education, and educational software programs such as Education Information Network and Morpa Campus.

During the elaboration phase, the teacher asked the students to make the third instruction as "3. Compare the solution suggestions of each member of your group for the problem situation and decide how to find the most appropriate solution for the group and draw your designs in detail in the space below" on the activity papers together with their group in order to associate science subjects with engineering discipline. While answering this instruction, the students chose the materials that they could use for the design, together with their group. After these steps were followed, the students started to make their designs with their group.

In the evaluation phase, the students who completed the design were asked to evaluate the information and activity learned by answering the questions in the "Let's Evaluate Ourselves" section as "4. Are there any parts that do not work when you test your design? What would you like to change if you wanted to redesign your layout?" and "5. When designing your product, please write down the used information". Then students were supposed to share their designs with class after completing the activity evaluation. At this time, the teacher evaluated the designs of the students and the process with the rubrics that prepared beforehand for the process and product evaluation. From the STEM activities evaluation rubric, students can get a minimum of 5 points and a maximum of 20 points. The rubric used in evaluating the activities is presented in Table 1.

Table 1. STEM Activities Evaluation Rubric

Qualifications	Weak (1p)	Medium (2p)	Good (3p)	Excellent (4p)
The group understands the problem situation and offers solutions.				
The group makes a suitable design for the problem situation.				
The design of the group is clear and straightforward.				
The group has created the design.				
The design of the group aimed to solve the problem situation.				

In the following weeks, the teaching of the lessons was implemented as explained in the first week. The activities carried out each week and the recommended course hours are given in table 3.

Table 2. List of activities and durations

Subject	Activity Name	Suggested Duration (hours)
Basic Machines	Leverage Design	4
	Reel Design	4
	Inclined Plane Design	4
	Spinning Wheel Design	4
	Compound Machine Design	4

Implementation in the Comparison Group

The comparison group were enabled to learn in terms of 5E learning model in accordance with the 2018 Science Curriculum. The textbook was used as a resource. In Turkey, the textbook is defined by the MoNE for all Pre-K and K12 education. The MoNE prepares the textbooks, publishes, and send them to the schools for free. During the entrance phase of the lesson, the teacher about the unit of basic machines showed the students a 50-second sequence from the video "The Story of Machines". About the video, the teacher asked the students questions such as "What did this documentary evoke in you?". In this way, the students' prior knowledge and readiness levels were tried to be determined. During the exploration phase, the teacher showed the students the pictures of the tools such as handcart, nut pick and tweezers and asked the students to explain what they were. Then, as additional examples, the teacher showed pictures of tools such as pieces of wood and water glasses and asked them to explain what happened in them. After this stage, the teacher asked the students to explain what similarities and differences exist between the first examples and the second examples. The teacher aimed to enable the student to discover information by using the discovery strategy. In the explanation phase of the lesson, after completing the exploration phase, the teacher started to teach students leverage. While the teacher was teaching the students the levers, the students were enabled to construct the basic concepts related to the subject in their mental structures by means of lecture, discussion, and question-answer method. During the elaboration phase, the teacher asked the students to do the activity "Let's Leverage" on the 8th grade science textbook around the subject they learned. At this stage, the teacher provided the students the opportunity to apply the gains they learned in the course in daily life. During the evaluation phase of the lesson, the teacher applied the questions in the activity to measure what the students learned about leverage. Other activities benefited from the textbook are presented in a Table 3.

Table 3. Activities of the comparison group

Reference textbook	Name of the activity	Page number
MoNE 8th grade science textbook	Let's Use Reels	p.165
	Let's Leverage	p.170
	The Story of the Stapler	p.178

In the next weeks, the activities were performed in the way similar to first week. The Basic Machines unit was covered in accordance with 5E model in the comparison group in the similar duration with the experimental group.

Data Analysis

The obtained data through ILSPS was computed in a Statistical Package for the Social Sciences (SPSS 22.0). The data was run for the normality analysis with the Shapiro-Wilk test which indicates whether the data transferred to the statistics program showed normal distribution. The test revealed that obtained ILSPS data was not overlap with the normal distribution ($p<0.05$). So, nonparametric tests were conducted for the data obtained through the ILSPS. Therefore, Mann Whitney U-Test was proceeded for comparing the groups as well as Wilcoxon Signed-Ranks Test. The normality analysis of the obtained data through ILSPS is provided in Table 4.

Table 4. ILSPS Pre and Post Test Normality Analysis Table

Groups	Test	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Experimental-Comparison	Pre	0.147	37	0.042	0.905	37	0.004
Experimental-Comparison	Post	0.228	37	0.000	0.822	37	0.000

The data obtained in the EKLS were also loaded into the statistical program and the necessary parameters were examined. In EKLS, correct responses scored with 1 point while false responses with zero. Then, the points that the students got in each question and their total test scores were calculated. The data were run for the normality analysis with the Shapiro-Wilk test which indicates whether the data transferred to the statistical program showed normal distribution. The analysis did not point to a normal distribution (p<0.05). So, Wilcoxon Signed-Rank in addition to Mann-Whitney U tests were considered to be appropriate for further analysis in terms of the normality analysis results did not indicated normal distribution and the sample size was the least in the ranking scale. The normality analysis of the obtained data through EKLS is given in Table 5.

Table 5. EKLS Pre and Post Test Normality Analysis Table

Groups	Test	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Experimental-Comparison	Pre	0.194	37	0.001	0.895	37	0.002
Experimental-Comparison	Post	0.186	37	0.002	0.900	37	0.003

Findings

Findings obtained through the ILSPS

Mann Whitney U-Test results between the pre-test and post-test ILSPS scores are given in Table 6.

Table 6. Comparison of ILSPS Pre Test and Post Test Scores

Test	Group	N	Mean Rank	Total Rank	U	P
Pre	Experimental	19	18.87	358.50	168.500	.939
	Comparison	18	19.14	344.50		
Post	Experimental	19	28.00	532.00	.000	.000
	Comparison	18	9.50	171.00		

In Table 6, there is no statistically significant difference between the inquiry learning perception levels between the groups regarding the pre-test scores of the groups (U = 168.500, p> 0.939). But there is a statistically significant difference in favor of the experimental group with respect to inquiry learning perception levels (U = .000, p <0.05). Mann Whitney U-Test results of ILSPS sub-dimensions are given in Table 7.

Table 7. Comparison of Post-Test Scores from ILSPS Sub-dimensions

Test	Subdimensions	Group	N	Mean Rank	Total Rank	U	P
Post Test	Positive perception	Experimental	19	28.00	532.00	0.00	0.00
		Comparison	18	9.50	171.00		
	Negative perception	Experimental	19	27.84	529.00	3.00	0.00
		Comparison	18	9.67	174.00		
	Inquiring the truth perception	Experimental	19	28.00	532.00	0.00	0.00
		Comparison	18	9.50	171.00		

In Table 7, there was a statistically significant difference in the sub-dimensions of the inquiry learning perception levels between the groups regarding the post-test scores groups (Positive perception U = 0.00, p <0.05; Negative perception U = 3.00, p <0.05; Inquiring the truth perception U = 0.00, p <0.05). It is seen that this significant difference is in favor of the experimental group in the post test. Paired comparison of ILSPS scores through Wilcoxon

Signed Ranks Test results are given in Table 8.

Table 8. Paired Comparison of ILPSP Pre and Post Test Scores

Group	Tests	Rank	N	Mean Rank	Total Rank	z	p
Experimental	Post Pre	Negative	0	.00	.00	-3.82	.000
		Positive	19	10.00	190.00		
		Equal	0	-	-		
Comparison	Post Pre	Negative	0	.00	.00	-3.72	.000
		Positive	18	9.50	171.00		
		Equal	0	-			

As seen in Table 8, there is a significant difference between groups ILSPS pre-test and post-test scores of the students participating in the study (For the experimental group, z = 3.82, p <0.05; For the comparison group, z = 3.72, p> 0.05). Regarding the mean rank and rank scores of the difference scores, the observed difference is in favor of the positive ranks. The results of the Wilcoxon Signed Ranks Test between the pre and post-test scores of the ILSPS sub-dimensions are given in Table 9.

Table 9. Comparison of the scores from ILSPS Sub-Dimensions

Group	Test	Subdimension	Rank	N	Mean Rank	Total Rank	Z	p
Experimental	Post Pre	Positive perception	Negative	0	0.00	0.00	-3.831	0.00
			Positive	19	10.00	190.00		
		Negative perception	Negative	0	0.00	0.00	-3.833	0.00
			Positive	19	10.00	190.00		
		Inquiring the truth perception	Negative	0	0.00	0.00	-3.834	0.00
			Positive	19	10.00	190.00		
Comparison	Post Pre	Positive perception	Negative	0	0.00	0.00	-3.737	0.00
			Positive	18	9.50	171.00		
		Negative perception	Negative	0	0.00	1.50	-3.558	0.00
			Positive	18	9.50	151.50		
		Inquiring the truth perception	Negative	0	0.00	0.00	-3.732	0.00
			Positive	18	9.50	171.00		

In Table 9, there is a significant difference between the pre-test and post-test scores of with respect to sub-dimensions of ILSPS in groups (For the experimental group: Positive perception z = 3.831, p <0.05; Negative perception z = 3.833, p <0.05; Inquiring the truth perception, z = 3.834, p <0.05. For the comparison group: Positive perception z = 3.737, p <0.05; Negative perception z = 3.558, p <0.05; Inquiring the truth perception, z = 3.732, p <0.05).

Findings Obtained through the EKLS

Mann Whitney U-test results regarding the significance between the EKLS are given in Table 10.

Table 10. Comparison of EKLS Pre and Post-Test Scores

Test	Group	N	Mean Rank	Total Rank	U	P
Pre	Experimental	19	20.71	393.50	138.500	0.318
	Comparison	18	17.19	309.50		
Post	Experimental	19	22.92	435.50	96.500	0.022
	Comparison	18	14.86	267.50		

In Table 10, there was no statistically significant difference in terms of engineering knowledge levels between the groups for the pre-test scores (U = 138.500, p> 0.05). Besides, there is a statistically significant difference regarding the post-test scores in terms of engineering knowledge (U = 96.500, p <0.05). Considering the mean rank, it is understood that the students participating in STEM supported science education have higher engineering knowledge than the students who do not.

The results of the Wilcoxon Signed Ranks Test for the paired comparison of the EKLS are given in Table 11.

Table 11. Paired Comparison of EKLS scores

Group	Tests	Rank	N	Mean Rank	Total Rank	z	p
Experimental	Post Pre	Negative	3	6.00	18.00	1.968	0.049
		Positive	10	7.30	73.00		
		Equal	6				
Comparison	Post Pre	Negative	9	5.06	45.50	0.443	0.658
		Positive	5	11.90	59.50		
		Equal	4				

As seen in Table 11, there is a significant difference between the pre-test and post-test scores of the groups obtained from the EKLS (z = 1.968 p <0.05). Regarding the mean rank and rank scores of the difference scores, the observed difference is in favor of the positive ranks. However, there is no significant difference between the pre-test and post-test scores of the comparison group obtained from the engineering knowledge level scale (z = 0.443, p> 0.05).

Discussion and Conclusion

Before the implementation, the students were not significantly different with respect to inquiry learning skill perception levels. This result can be interpreted as the inquiry learning skill perception levels of the students were close to each other. It can be said that the students participating in the study come from the same environment, their demographic characteristics are close to each other, and they have received education and training under the same conditions until this process.

The post-test scores of the groups were significantly different with respect to inquiry learning skill perception levels in favor of the experimental group. So, the STEM supported science teaching was effective on students' perception of inquiry learning skills. This situation is thought to derive from the students following the engineering design process while doing the activities in STEM supported education. Because, while students are doing the "Leverage Design" activity, they experience the engineering design process such as scientific inquiry and research in addition to experiment set-up. Thus, the engineering design process has an effect on students' perception of inquiry learning skills. It is possible to find many studies supporting this result obtained in this study. In many studies on this subject, it has been found that students' inquiry skills and learn by doing and experiencing during the process have an effect on inquiry learning skills perception (Brunsell, 2012; Purzer et al., 2015). In the comparison group, the subjects were applied by following the steps of the 5E model, and the determined subjects were questioned by the students, especially in the exploration and transfer steps. For example, on leverage, the students questioned about recognizing, classifying and functions of the materials presented to them. The inquiry experience that students were exposed to during the learning process had an impact on their inquiry-based learning perceptions. When the literature is examined, it can be seen that the activities carried out by adopting the 5E model increase students' inquiry skills (Desouza, 2017).

It was determined that the significant difference before and after the implementation between the skills scores of students' inquiry learning perception levels between the groups in favor of post-test. The implementations were effective on inquiry learning skills. The emergence of such a result in the experimental group is possible to be derived from the STEM activities implemented to the experimental group were prepared according to the inquiry-based learning approach. The 5E learning model has an effect on inquiry learning skills due to its features such as the inclusion of inquiry-oriented questions in the activities applied in entrance, exploration and evaluation stages, and its ability to generate solutions appropriate to the problem situation. In addition, questioning the information to be used in the solution of the problem in the exploration step, investigating and analyzing it, in the evaluation step, questioning the information they learned and identifying the non-working parts of their designs may have revealed this difference or supported the questioning skill perception (Johns & Mentzer, 2016; Yıldırım, 2016). This situation is also thought to be effective in the emergence of this result, while the student was producing a solution proposal to the problem situation during the implementation period, showed a tendency to question against the problem and had the opportunity to solve the problem (Siew & Ambo, 2020). In many experimental studies in which STEM supported science teaching was performed, the test scores were significantly different from each other in favor of posttests (Kırıcı & Bakırcı, 2021). Thus, the obtained result coincides with the previous study results on this subject.

Before and after the implementation, the ILSPS scores of the comparison group were significantly different. Besides, the 5E learning model was effective on comparison group students' perception of inquiry learning skills. Discussions on the subject in the exploration step and open-ended questions about the inquiry skills included in the activities in the textbook used in the elaboration step are thought to be effective in the emergence of this situation (Akben & Köseoğlu, 2015; Changtong, Maneejak & Yasri, 2020).

In addition, the experimental group's pre-test scores were slightly different from comparison group with respect to engineering knowledge levels. This can be interpreted in the way that students are close and similar in terms of engineering knowledge levels. This similarity can be attributed to the close socioeconomic levels of the students or their taking lessons from the same teachers. This situation is seen as a situation that has emerged in many experimental studies (Capobianco, Radloff & Lehman, 2021; Kırıcı & Bakırcı, 2021).

Moreover, the experimental group's post-test scores were different from comparison group with respect to engineering knowledge levels. This revealed that STEM-supported science teaching in experimental group was effective on engineering knowledge levels. While developing STEM activities, the researcher's consideration of the engineering process cycle may have reflected in the elaboration step of the teaching (Bozkurt, 2014; Park, Park & Bates, 2018). The teaching process given to the students was carried out on STEM activities, taking into account the engineering integration process. In STEM activities, students were given a problem situation, they were asked to develop solution suggestions specific to this problem situation, they were asked to create a design suitable for the solution suggestions that they found and draw these designs. In this process, students' thinking like an engineer and making designs contributed to the emergence of this result (Astuti, Rusilowati & Subali, 2021; Ercan, 2014).

Furthermore, the experimental group scores were not significantly different before and after the implementation with respect to engineering knowledge levels. It indicates that STEM-supported science learning experienced provided to the experimental group was efficient at the engineering knowledge level of the eighth-grade students. This result underlines inclusion of engineering design process steps into STEM activities is effective in the emergence of this result (NRC, 2012; Ünlü & Dökme, 2017). This result may be occurred due to the implementations such as revealing the problem situation of STEM activities in the entrance step, developing possible solutions in the exploration step, determining the most appropriate solution in the explanation step with the discussion technique, making and testing the prototype in the elaboration step, and finally sharing and improving the prototype in the evaluation step (Spaulding, Kennedy, Rozsavölgyi & Colon, 2020).

Finally, the comparison group scores were not significantly different before and after the implementation with respect to engineering knowledge levels. This can be interpreted as the ineffectiveness of science teaching in the comparison group. It can be said that the fact that the students' thinking as an engineer is not emphasized due to the activities in the textbook do not completely include the engineering design process. Also, the activities of the 5E learning model, except for the exploration and elaboration step, were not suitable for the engineering design process, which may have led to this situation.

Implications

Other units of the science course should also be studied in order to observe more clearly the views of STEM supported science teaching towards students' engineering knowledge levels, inquiry learning skills perceptions and STEM.

The study has only been conducted with eighth grade students, and studies should be conducted with students from different education levels. Studies should be carried out on the basis of mathematics, technology design courses and interdisciplinary approach in addition to the science course.

STEM workshops should be established in order to clearly see the effect of engineering and technology. Thus, better integration can be performed for engineering and technology disciplines.

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References

Akben, N., & Köseoğlu, F. (2015). Inquiry-based learning and 5E model in laboratory practices: A professional development program for prospective classroom teachers. *Ankara University, Journal of Faculty of Educational Sciences*, *48*(1), 161-197.

Astuti, N. H., Rusilowati, A., & Subali, B. (2021). STEM-based learning analysis to improve students' problem solving abilities in science subject: A literature review. *Journal of Innovative Science Education, 10*(1), 79-86.

Aydın, G., Saka, M., & Guzey, S. (2018). Engineering knowledge level measurement scale for students in grades 4 through 8. *Elementary Education Online*, *17*(2), 750-768.

Balım, A. G., & Taşkoyan, S. N. (2007). Developing measurement of inquiry learning skills perception in science. *Journal of Buca Faculty of Education*, 21, 58- 63.

Benek, İ., & Akçay, B. (2022). The effects of socio-scientific STEM activities on 21st century skills of middle school students. *Participatory Educational Research, 9*(2), 25-52.

Bowen, B. & Shume, T. (2020). Developing workforce skills in K-12 classrooms: How teacher externships increase awareness of the critical role of effective communication. *Journal of STEM Education*, *21*(1), 73-80.

Bozkurt, E. (2014). *The effect of engineering design-based science instruction on science teacher candidates' decision-making skills, science process skills and perceptions about the process* (Doctoral dissertation). Gazi University, Ankara.

Brunsell, E. (2012). The engineering design process. https://www.teachengineering.org/k12engineering/designprocess. Date of access: 13.11.2021.

Büyüköztürk, Ş. (2017). *Data analysis handbook for social sciences*. Ankara: Pegem Akademi Publishing.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30–35.

Capobianco, B. M., Radloff, J., & Lehman, J. D. (2021). Elementary science teachers' sense-making with learning to implement engineering design and its impact on students' science achievement. *Journal of Science Teacher Education*, *32*(1), 39-61.

Changtong, N., Maneejak, N., & Yasri, P. (2020). Approaches for Implementing STEM (Science, Technology, Engineering; Mathematics) Activities among Middle School Students in Thailand. *International Journal of Educational Methodology*, *6*(1), 185-198.

Çepni, S. (2011). *Introduction to research and project studies*. Trabzon: Celepler Printing.

Çorlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers in the age of innovation. *Education and Science*, *39*(171), 74-85.

Desouza, J. M. S. (2017). Conceptual play and science inquiry: using the 5E instructional model. *Pedagogies: An International Journal*, 12, 340 - 353.

Dugger, W. E. (2010). Evolution of STEM in the United States. *Presented at the 6th Biennial International Conference on Technology Education Research*, Gold Coast, and Queensland.

Ercan, S. (2014). *The usage of engineering practices in science education: Design based science learning* (Doctoral dissertation). Marmara University, İstanbul.

Harwell, M., Moreno, M., Phillips, A., Guzey, S. S., Moore, T. J. & Roehrig, G. H. (2015). A study of STEM assessments in engineering, science and mathematics for elementary and middle school students. *School Science and Mathematics*, 115(2), 66-74.

Hu, H.-W., Chiu, C.-H. & Chiou, G.-F. (2019). Effects of question stem on pupils' online questioning, science learning, and critical thinking, *The Journal of Educational Research*, *112* (4), 564-573.

Johns, G., & Mentzer, N. (2016). STEM integration through design and inquiry. *Technology and Engineering Teacher*, *76*(3), 13.

Kalaycı, Ş. (2005). *SPSS applied multivariate statistical techniques*. Ankara: Noble Publication Distribution.

Kennedy, T. & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, *25*(3), 246–258.

Kırıcı, M. G. & Bakırcı, H. (2021). The effect of STEM supported research inquiry-based learning approach on the scientific creativity of 7th grade students. *Journal of Pedagogical Research*, 5(2), 19-35.

Luo, T., So, W. W. M., Li, W. C., & Yao, J. (2021). The development and validation of a survey for evaluating primary students' self-efficacy in STEM activities. *Journal of Science Education and Technology*, *30*(3), 408-419.

Ministry of National Education (2016). STEM education report. June, Ankara. Access address is http://yegitek.meb.gov.tr/STEM_Egitimi_Raporu.pdf. Access Date: 15.06.2020.

Ministry of National Education (2018a). *Curriculum of science courses of primary education institutions (3, 4, 5, 6, 7 and 8th grades)*. Ankara: State Books Publishing House.

Ministry of National Education (2018b). Turkey's Education Vision 2023. Access address is: http://2023vizyonu.meb.gov.tr/doc/2023_VIZYON_ENG.pdf

National Science and Technology Council (2013). *Federal science, technology, engineering and mathematics education 5-year strategic plan*. Washington.

National Research Council (NRC). (2012). *A Framework for k-12 science education: practices, crosscutting concepts, and core ideas*. Washington DC: The National Academic Press.

Park, D., Park, M., & Bates, A. (2018). Exploring young children's understanding about the concept of volume through engineering design in a STEM activity: A case study. *International Journal of Science and Mathematics Education*, *16*(2), 275-294.

Purzer, S., Goldstein, M., Adams, R., Xie, C. & Nourian, S. (2015). An exploratory study of informed engineering design behaviors associated with scientific explanations. *International Journal of Stem Education*, *2*(9), 1-12.

Siew, N. M. & Ambo, N. (2020). The scientific creativity of fifth graders in a STEM project-based cooperative learning approach. *Problems of Education in the 21st Century*, 78(4), 627-643.

Sinatra, G. M., Mukhopadhyay, A., Allbright, T. N., Marsh, J. A. & Polikoff, M. S. (2017). Speedometry: A vehicle for promoting interest and engagement through integrated STEM instruction. *The Journal of Educational Research*, *110* (3), 308-316.

Spaulding, D. T., Kennedy, J. A., Rozsavölgyi, A, & Colon, W. (2020). Differences in outcomes by gender for peer mentors participating in a stem persistence program for first-year students. *Journal of STEM Education*, 21(1), 5-10.

TÜSİAD (Turkish Industrialists and Businessmen Association) (2017). Responsibility Statement Report 2016-2017. https://tusiad.org/tr/yayinlar/raporlar/item/9953-tusiad-global-compact-responsibility-statement-report-coe. Access date: 20.09. 2018.

Ünlü, K. Z. & Dökme, İ. (2017). Gifted Children' Images about STEM's E. *Trakya Journal of Education*, 7(1), 196-204.

Yıldırım, B. (2016). *An examination of the effects of science, technology, engineering, mathematics (stem) applications and mastery learning integrated into the 7th grade science course* (Doctoral dissertation). Gazi University, Ankara.