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Investigación de los efectos de las actividades STEM en la actitud STEM en estudiantes superdotados

Investigation of the effects of STEM activities on STEM attitude in gifted students

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Resumen

El efecto de las actividades STEM en la actitud STEM de los estudiantes superdotados y el rendimiento STEM se examinaron en el presente estudio. Los participantes son 23 estudiantes superdotados que estudian en el Centro de Ciencias y Arte en el año académico 2020-2021. Las actividades se completaron en 54 horas lectivas en el marco del proceso de diseño de ingeniería. El método de la investigación se determinó como diseño mixto secuencial explicativo. Se utilizó un diseño experimental de grupo único como método cuantitativo y el estudio de caso como método cualitativo. Los datos se recopilaron con la escala de actitud STEM (SAS) y un formulario de entrevista semiestructurada al estudiante en el estudio de caso. Al final de las actividades STEM, el rendimiento de los estudiantes se evaluó con la rúbrica de evaluación STEM (SAR). Como resultado, hubo una diferencia significativa entre las puntuaciones medias previas y posteriores a la prueba de actitud STEM de los estudiantes después de la aplicación STEM. La actitud STEM no difirió significativamente según el género y el grado, mientras que hubo una diferencia estadísticamente significativa a favor de las alumnas superdotadas en la subdimensión de ingeniería y tecnología. De acuerdo con las opiniones de los estudiantes superdotados, se ha entendido que las aplicaciones STEM mejoraron las actitudes de los estudiantes y sus habilidades del siglo XXI.

Palabras clave: STEM, estudiantes superdotados, actitud, diseño mixto secuencial explicativo, logro STEM

Abstract

The effect of STEM activities on gifted students' STEM attitude and STEM achievement were examined in the current study. The participants are 23 gifted students studying at the Science and Art Center in the 2020-2021 academic year. The activities were completed in 54 lesson hours

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within the framework of the engineering design process. The method of the research was determined as explanatory sequential mixed design. A single group experimental design was used as a quantitative method and the case study was used as a qualitative method. Data were collected with the STEM attitude scale (SAS), and a semi-structured student interview form in the case study. At the end of the STEM activities, students' achievement was evaluated with the STEM assessment rubric (SAR). As a result, there was a significant difference between students' STEM attitude pretest and posttest mean scores after the STEM application. The STEM attitude did not differ significantly according to gender and grade level, while there was a statistically significant difference in favor of gifted female students in the sub-dimension of engineering and technology. According to the opinions of gifted students, it has been understood that STEM applications improved students' attitudes and their 21st century skills.

Keywords: STEM, gifted students, attitude, explanatory sequential mixed design, STEM achievement

Introduction

STEM education can be defined as the integrated teaching of real-life course content by integrating science, technology, mathematics, and engineering disciplines (Sanders, 2012; Moore, et al., 2013). The use of science, technology, engineering, and mathematics disciplines together provides the opportunity for students to gain more permanent and deeper learning and to have the opportunity to apply what they have learned (Wicklein & Schell, 1995). Students educated through STEM are expected to have skills defined as 21st century skills in the literature such as creative thinking, problem solving, self-confidence, logical thinking, communication, using technology at a high level, competitiveness, and critical thinking (Bybee, 2010; Morrison, 2006). Therefore, STEM education uses a student-centered approach to provide students with these skills (Stehle & Peters-Burton, 2019).

Thus, with STEM, students find solutions to real-world problems, make designs, and ultimately develop products for the problem (Gomez & Albrecht, 2013; Margot & Kettler, 2019). Based on various sources, it can be stated that this approach contributes greatly to students' acquisition of high-level cognitive skills, the development of their affective characteristics, and their career planning. In this way, students can contribute to the world where technology and science develop with STEM.

The attitudes of students towards STEM, which is the most important change movement in the field of education of the 21st century, are extremely important. Determining the attitudes towards STEM will contribute to the determination of the workforce potential that countries will need in the future and to make the necessary arrangements to increase the workforce (Kennedy, Quinn & Taylor, 2016). Current efforts by both private companies and public institutions to improve society are increasing the demand for professions with STEM skills (Rothwell, 2013).

The most critical period for students who will perform STEM professions that countries will need in the future is secondary school age (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013). Giving the necessary importance to STEM education at the secondary school level can improve students' interests, attitudes and future goals towards STEM fields. Students' positive attitudes towards STEM fields will enable them to be willing to plan their careers in these fields (Wang, 2013; Christensen, Knezek, & Tyler-Wood, 2015). In the literature, there are many studies showings that students' STEM attitudes and career interests are formed during the secondary school years (Maltese & Tai, 2011; Baran et al., 2015; Karahan et al., 2015). For this reason, gifted students at secondary school age, which is the critical period in which STEM attitudes will develop, were selected as the participant group in this study.

There are many studies showing that STEM is one of the important approaches that can be used to develop the skills of gifted students with an effective learning environment (Schroth & Helfer, 2017; Tofel-Grehl & Callahan, 2017; Şen & Kiray, 2021). STEM is a suitable education model to provide gifted students with the necessary skills, develop creative and original solutions to problems, and direct them to STEM-related professions (Stoeger, Hopp & Ziegler, 2017). Yoon & Mann (2017) determined that gifted students are more likely to pursue a career in STEM. STEM provides an important basis for gifted students to develop their skills in STEM fields (Robinson, et al., 2014).

STEM education is of great importance in the training of future engineers, mathematicians, and scientists. If countries use STEM education effectively, they will contribute to the positive development of their economies (Fan & Ritz, 2014). Attempting to identify the factors that influence young people's responses to STEM courses and careers, their participation in STEM, their attitudes, interests, and choice of STEM fields remains a policy priority in many countries (Regan & DeWitt, 2015). Therefore, in recent years, with the understanding of the importance of STEM education in the world, studies examining students' attitudes towards STEM activities have been carried out (Irkıçatal, 2016; Guzey & Aranda, 2017; Kalik & Kırındı, 2022). However, studies examining the STEM attitudes of gifted students are insufficient. In this study, the effects of gifted secondary school students' STEM attitudes in terms of gender and grade level variables will be examined by integrating the data obtained from the attitudes of gifted students towards STEM, their achievement scores from STEM activities, and their views on STEM activities.

Methodology

Design

The design of this research was determined as explanatory sequential mixed design. This design consists of two phases, starting with the quantitative phase, followed by the qualitative phase, which aims to explain or improve the quantitative results. It is a mixed method design in which the researcher tries to explain the quantitative results by carrying out a quantitative stage and using a qualitative method (Creswell & Plano-Clark, 2018). As a quantitative design in the study, a single group pretest posttest experimental design, one of the experimental design types, was used.

Single group experimental design is a type of experimental research used to test whether an application causes an effect in a group of participants (Plano-Clark & Creswell, 2015). A case study was used as a qualitative pattern. Case study requires developing an in-depth analysis of a single or multiple situations (Yin, 2003). Data in the case study includes interview data, document data (program records, journals, etc.), statements of others about the situation and contextual information (Patton, 2014).

Participants

The study group includes 23 gifted students studying at Salihli Science and Art Center in the spring semester of the 2020-2021 academic year. The study group was selected with the convenient sampling method (Patton, 2014), one of the purposive sampling methods, considering the school where the researcher works as a teacher. In the determination of the experimental group, the researcher's physical accessibility to the application area and the convenience it provides in terms of application. The distribution of the subjects according to gender and class is presented in Table 1.

Table 1
Demographics of participants

Variable	Category	N	(%)
Gender	Female	10	44
	Male	13	56
	5th	7	30
Grade	6th	8	35
	7th	8	35

According to the Table 1, 10 (44%) of the 23 students who make up the experimental group are female students and 13 (56%) are male students. 7 (30%) of these subjects are at the 5th grade, 8 (35%) at 6th grade, and 8 (35%) at 7th grade.

Data collection tools

As a quantitative data collection tool, STEM Attitude Scale (SAS) developed by Faber et al. (2012) and adapted into Turkish by Özcan and Koca (2018) was used. SAS consists of four dimensions: Science, Mathematics, Engineering and Technology, and 21st century skills. It consists of 8 items in the mathematics sub-dimension, 9 items in the science sub-dimension, 9 items in the Engineering and Technology sub-dimension, 11 items on 21st century skills, and a total of 37 items. The scale is a 5-point Likert type and includes expressions as "strongly agree", "agree", "undecided", "disagree" and "strongly disagree". The other quantitative data collection tool of the research is the STEM Assessment Rubric (SAR) developed by Kocaman (2022).

Reliability and validity

The SAS Cronbach Alpha coefficient was specified as .91 for the entire scale. In this study, the Cronbach Alpha reliability coefficient of SAS was calculated as $\alpha = .905$ for pre-test and $\alpha = .876$ for post-test. The approach to ensure reliability in rubrics is to determine the agreement between raters (Moskal & Leydens, 2000).In the study, the rubric was scored by two independent raters to determine the reliability level of the rubric. After the scoring results, Weighted Kappa analyzes were made and the reliability results of the rubric were obtained.

Table 2
Reliability results for SAR

Application	Weighted Kappa Coefficient	N
1st	0,757	23
2nd	0,704	23
3rd	0,714	23
4th	0,809	23
Total	0,835	23

Within the scope of reliability, the Weighted Kappa value of rubric in application 1 is 0.757; 0.704 in the 2nd application; 0.714 in the 3rd and 0.809 in the 4th while it was calculated as 0.835 in the entire rubric. Kappa value should be 0.70 and above in order to have an acceptable fit between raters (Stemler, 2004). According to the calculations, it is seen that the agreement between the raters of SAR is acceptable.

Semi-structured student interview form was used as a qualitative data collection tool. For this reason, first of all, national and international sources related to STEM attitude were scanned. Questions were formed with the results obtained from the sources and studies related to STEM attitude. An expert evaluation form was prepared to be used for the validity study of the interview questions. Expert evaluation for grammar corrections were done by 2 literature teachers and 1 field expert; content controls were made by 1 field expert. The interview form, which was corrected in line with expert opinions, was piloted with 3 students.

As a result of the pilot application, the interview form was finalized. In the student interview form, there are five open-ended questions: “Would you like to have STEM activities in the lessons in your school? Why? What kind of differences can you tell when you compare your STEM activities with other course activities? At what stage did you have difficulty in STEM activities? Why? What were the positive and negative aspects of STEM activities? What skills do you think STEM activities can improve in students? Why?”

Data collection

In the study, a pre-test was conducted with SAS to determine the level of STEM attitudes of the study group. Then the STEM application was carried out. During the application, after each activity, students' SAR and STEM achievements were evaluated. After each application, students' opinions about the STEM application were taken. At the end of the application, the posttest was applied to the study group to determine whether there was a change in STEM attitudes. STEM application process explained in detail below.

Application Process

The applications took 54 class hours in nine weeks in the STEM workshop course at the Science and Art Center. Separate groups were formed for each grade level. The application was carried out with each group in a separate lesson hour. STEM activities, “Let's Make Anemometer”, “Wave Machine”, “I'm coding my game” and “I'm designing a 3D Animal shelter”, were organized by the researcher with engineering design-based teaching. At the beginning of the application process, detailed information was given to the students. Activities during implementation applied as part of the cycle for the engineering design process offered by (2011).

According to the steps of the cycle introduced by Hynes et al. (2011) students formed groups and worked in collaboration. They identified the problems of the activities with the given problem scenario. In this process, group members brainstormed and developed possible solutions. As a result of the discussion within the group, the best solution was determined, and then the product design was made for the problem. In all these processes, the researcher acted as a guide to the groups. Then the designs were tested with the group members and the researcher. Solution suggestions were discussed with other groups for the products that failed. The designs were rearranged and finalized and presented to the class. At the end of each activity, the researcher evaluated the students with SAR. The content information about the activities carried out during the implementation process is given as follows.

Table 3
Aims and objectives of STEM applications

Application	Aim	Objectives
Let's Make Anemometer	Like meteorologists who study the weather, they make anemometers using paper cups to measure wind speed and count the rotations of the wind.	Explains the formation of the wind. Measures the diameter of the circle.
Wave Machine	The wave machine shows how waves transfer energy from one place to another. Observing the flow of energy and measuring frequency through making a wave machine using clay and skewers.	Calculates the number of waves (frequency) that pass a given point per second. Observes the transfer of energy.
I'm coding my game	Designing a game with coding by realizing what the algorithm does.	Develops solution-oriented algorithm design proposal. Coding with computer aided software program (scratch).
I'm designing a 3D Animal shelter.	Designing in 3D by using geometric shapes.	Transforms the draft drawings into three-dimensional visuals with the help of computer (Tinkercad). Knows the shelter needs of animals.

Data analysis

Before and after the application, SAS was applied to participants. In the research, first of all, the normality test was conducted to determine which test to use for comparing whether there was a significant difference between the STEM attitudes of the study group before and after the application. When the number of observations is low ($n<50$), the Shapiro Wilks test is more powerful than the Kolmogorov Smirnov test (Büyüköztürk, 2010: 42). According to the Shapiro-Wilk test, normality was observed ($p<.05$). The data analysis applied in the study and its purpose are given in Table 4.

Table 4
Data collection tools and types of analysis

Aim	Data Collection Tool	Type of Analysis
Reliability of SAS	SAS	Cronbach alfa
Reliability of SAR	SAR	Weighted Kappa
To determine whether there is a significant difference between the average scores of students regarding STEM attitude.	SAS	Paired t test
To determine whether there is a significant difference between the pretest and posttest scores of STEM attitudes in terms of gender.	SAS	Independent t test
To determine whether there is a significant difference between the pretest and posttest scores of STEM attitudes in terms of grade level.	SAS	ANOVA
Evaluate the effect of each STEM activity on students	SAR	Descriptive analysis (Mean, Standard deviation, min. and max. values)
To get the opinions of the students after the application.	Semi-structured student interview form	Content analysis (Atlas ti 8)

In this section, impact analyzes were made on the quantitative findings in order to evaluate the data in a healthier way and the comments were based on these analyzes. The most commonly used calculation of the effect size is developed by Cohen (d) (Yıldırım & Yıldırım, 2011). As a general recommendation, Cohen says that the effect size can be defined as weak if the d value is less than 0.2, medium if it is 0.5, and strong if it is greater than 0.8. However, it should be noted that there may be special cases where even a d value of 0.2 can be considered as a strong effect (Cohen, 1988; Kılıç, 2014).

Qualitative data were written by two researchers to ensure inter-rater reliability and analyzed thematically. Interview data was first analyzed using ATLAS.ti version 8 text analysis software to establish relationships between words and phrases. The researcher and co-observer met weekly for nine weeks to compare emerging issues and discuss relevant narratives in the data. In the study, a consensus was reached on the creation of four main themes: 21st century skills, learning, positive qualities, and negative qualities. Four main themes, codes and quotations from the participants are explained in detail in the findings section.

Results

Does gifted students' STEM attitude differ significantly after STEM activities? For this sub-problem, it was examined whether there was a significant difference between the STEM attitudes of the students before and after the application. Before the analysis of the problem, the results of the normality test of the data obtained from the students' pretest and posttest SAS are given in Table 5.

Table 1
Distribution of data

Groups	N	Kolmogorov Smirnov	ShapiroWilk	Skewness	Kurtosis	Standardized Error
Pre-test	23	,200	,704	,185	-,832	,05864
Post-test	23	,200	,407	,243	-,593	,06660
Difference (Pre- and post)	23	,200	,821	,302	,024	,04527

Normality was observed according to Shapiro-Wilk test ($p<.05$). Skewness and kurtosis values are compared with ±1.96 value for 5% significance level. If the values found are greater than ±1.96, the assumption of normality is not provided (Büyüköztürk, 2010:42). When the skewness value (.302) and kurtosis value (.024) are examined in the table, it is seen that it provides normality. Paired t-test results for students' pre- and post-test scores are given in Table 6.

Table 2
Pre and post test analysis results of SAS

	Grup	N	$\bar{X}$	Sd	Df	t	p	d
SAS	Pre-test	23	3.47	.281	22	14,09	.00	0.213
	Post-test		4,11	.319				

Table 6 shows that there is a statistically significant difference in favor of post-test scores (t= 14.09, p.00). SAS post-test mean score ($\bar{X}$ = 4.11) is higher than pre-test mean score ($\bar{X}$ =

3.47). At this point, an effect analysis was performed in order to evaluate the findings of the study more accurately, and the Cohen's d value was found to be 0.213. It shows that the STEM activities have a moderate level effect on the difference between the pre-test and post-test average scores. In Table 7, the results of the pretest and posttest analysis regarding the sub-dimensions of SAS are given.

Table 3

Pre and post test analysis results for sub-dimensions of SAS

Sub-dimension	Group	N	$\bar{X}$	Sd	Df	t	P	d
Mathematics	Pre-test		3,44	.370	22	7,26	.00	,150
	Post-test	23	4,01	.386				
Science	Pre-test		3,36	.340	22	7,59	.00	,223
	Post-test	23	4,37	.542				
Engineering and Technology	Pre-test		3,57	.366	22	10,95	.00	,175
	Post-test	23	4,21	.363				
21st century skills	Pre-test		3,50	.312	22	8,913	.00	,203
	Post-test	23	4,13	.308				

In Table 7, a significant difference was found for the sub-dimension of the mean scores of the pre- and post-test in the sub-dimensions of mathematics (t= 7.26, p.= .00), science (t= 7.59, p.= .00), engineering and technology (t= 10,95, p.= .00) and 21st Century skills (t= 8.913, p.= .00). Mathematics, science, engineering and technology, 21st century skills sub-dimension post-test average scores are higher than pre-test average scores.

According to these findings, it was seen that the experimental application was significantly effective in favor of the post-test in the sub-dimensions of SAS. At this point, an impact analysis was carried out in order to better evaluate the findings of the research and the effect sizes (Cohen's d value) were found to be 0.150 for the mathematics sub-dimension, 0.223 for the science sub-dimension, 0.175 for the engineering and technology sub-dimension, and 0.203 for the 21st century skill sub-dimension. It shows that STEM activities have a weak effect on STEM sub-dimensions.

By the other hand, does gifted students' STEM attitude differ significantly according to gender after the application of STEM activities? First of all, normality test was performed. It is seen that the data are normally distributed according to gender (p= ,974, ,737>.05). T-test results of SAS and sub-dimension scores by gender are given in Table 8.

Table 8

Gender related T-test results for pre- and post-test results of SAS

Sub-dimension	Gender	N	X	Sd	t	df	p
Mathematics	Female	10	,525	,415	-,501	21	,621
	Male	13	,605	,356			
Science	Female	10	,822	,374	,999	21	,329
	Male	13	,632	,501			
Engineering and Technology	Female	10	,766	,218	2,201	21	,037
	Male	13	,529	,280			
21st century skills	Female	10	,681	,359	,709	21	,486
	Male	13	,580	,324			
SAS	Female	10	.702	.230	1,29	22	,210
	Male	13	.586	.200			

According to Table 8, there is no significant difference between the pretest and posttest scores of the SAS sub-dimensions by gender, except for the engineering and technology sub-dimension (p=.037). In the engineering and technology sub-dimension average scores, the average score of female students was higher than the average score of male students. It can be said that female students' attitudes towards engineering and technology are higher than male students. In this case, does gifted students' STEM attitude differ significantly according to grade level? The results of the ANOVA test for participants' grade levels after the application are given in Table 9.

Table 9

ANOVA test results for the grade level

Grade	N	X.	Sd	F	p
5th	7	,5985	,21702	,146	,865
6th	8	,6554	,19422		
7th	8	,6520	,26061		
Total	23	,6369	,21711		

According to the results of the analysis, it is seen that there is no significant difference in the STEM attitude levels of the study group according to the grade levels (F=.146, p=.865). The STEM attitude level of the study group does not change significantly depending on the grade level. For the other hand, what is the level of achievement of STEM activities for gifted students? The level of achievement of STEM activities was determined by the analysis of data collected by SAR and represented in Table 10.

Table 10
SAR Results

	N	Min.	Max.	X	Sd
Rater 1	23	17,00	27,75	22,239	2,827
Rater 2	23	17,50	27,50	22,10	2,62
Total	23	17,25	27,63	22,173	2,714

According to Table 10, the average score of gifted students by co-observers was determined as 22,173. The average scores of gifted students for each STEM activity are given in Figure 1.

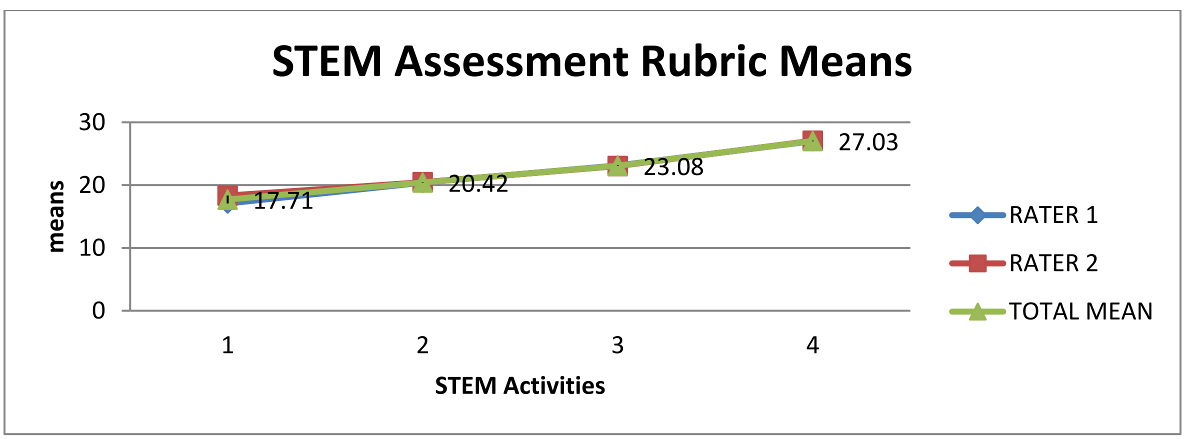

Figure1. SAR averages of the study group determined by the co-observers

According to the findings obtained from the SAR and shown in Figure 1, it is seen that there is an increase in the average scores of the students from the first activity to the last application. The mean score of the first activity was calculated as 17.71, 20.42 in the second activity, 23.08 in the third, and 27.03 in the fourth. The results of SAR by gender are given in Table 11.

Table 11
SAR Results for gender

Gender	N	Min.	Max.	X	Sd
Female	10	18,00	27,63	22,21	2,705
Male	13	17,25	26,50	22,14	2,831
Total	23	17,25	27,63	22,17	2,714

According to the SAR results represented in Table 11, it is seen that the average score of girls (22.21) is slightly higher than the average score of boys (22.14). As a result, it can be said that female students are slightly more successful than male students in STEM application. SAR results by class level are given below in Table 12.

Table 12
SAR Results for grade

Grade	N	Min	Max	X	Sd
5th	7	17,25	24,88	20,89	2,442
6th	8	18,00	26,50	22,85	2,868
7th	8	19,63	27,63	22,60	2,590
Total	23	17,25	27,63	22,17	2,714

According to Table 12, the classes with the highest average in SAR were determined as 6th (22.85), 7th (22.60) and 5th (20.89), respectively. According to this finding, the average scores of gifted students in STEM activities according to the grade level were very close to each other, and it was determined that the 6th grade was the most successful class. In this case, the follow question is been made: what are the opinions of gifted students about STEM activities? The interview data obtained from the students regarding the STEM application process were analyzed with the Atlas.ti8 package program. The theme and codes network of the analysis is given in Figure 2.

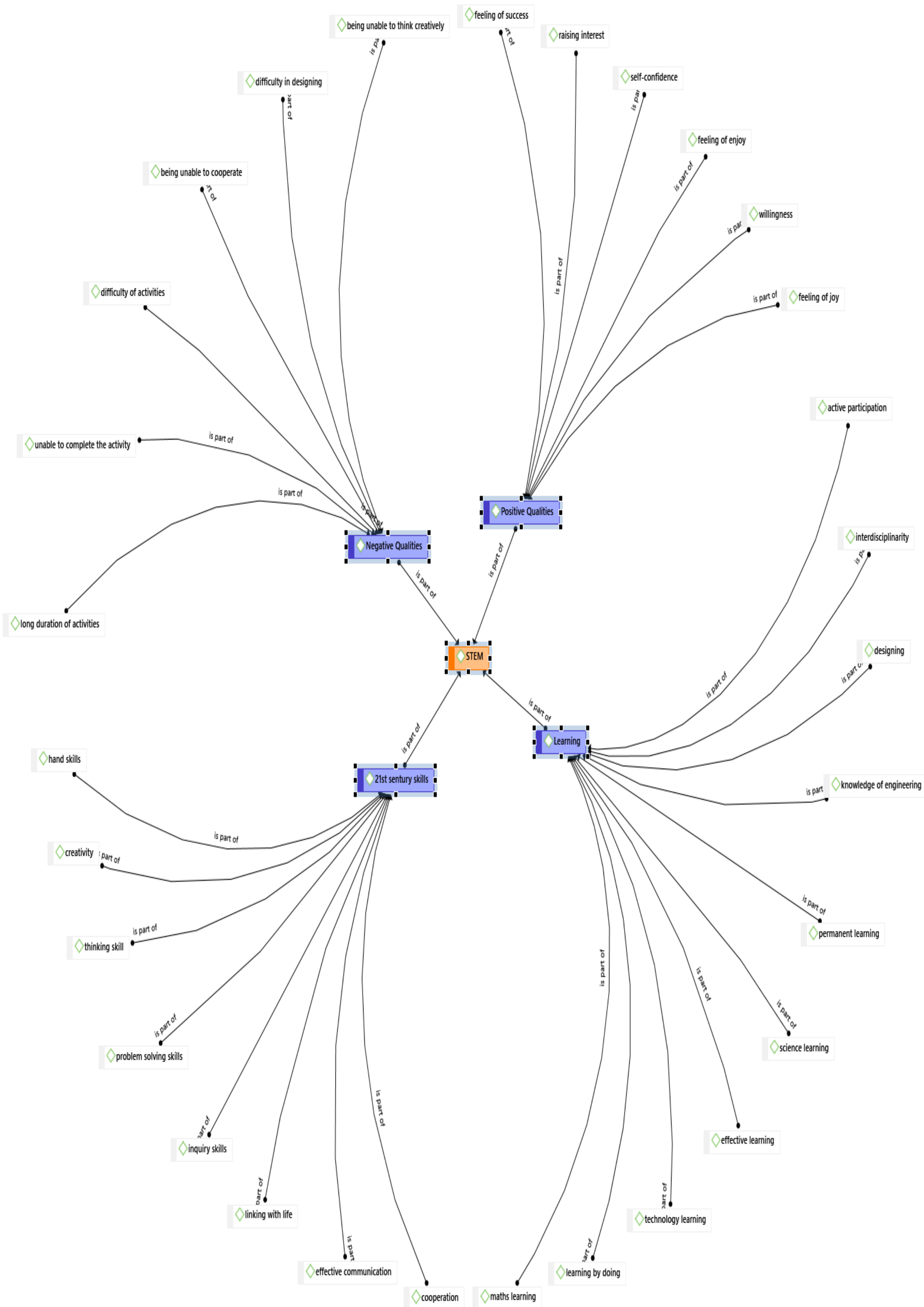

Figure 2. Network of STEM Opinions

As a result of the analysis of the network of categories and codes, the frequency and percentage values are given in Table 13.

Table 13
Findings related to categories and codes in STEM opinions

Category	**Kod**	f	%
Positive Qualities	Feeling of success	7	17,9%
	Feeling of joy	9	23,1%
	Raising interest	4	10,3%
	Willingness	10	25,6%
	Self-confidence	6	15,4%
	Feeling of enjoyment	3	7,7%
	Total	39	100%
21st century skills	Inquiry skill	7	7,9%
	Effective communication	9	10,1%
	Creativity	9	10,1%
	Cooperation	32	35,9%
	Problem-solving skill	13	14,6%
	Linking with life	7	7,9%
	Thinking skill	9	10,1%
	Hand skills	3	3,4%
	Total	89	100%
Learning	Active participation	18	20%
	Interdisciplinarity	9	10%
	Effective learning	19	21,2%
	Permanent learning	3	3,3%
	Learning by doing	6	6,7%
	Science learning	5	5,5%
	Mathematics learning	9	10%
	Knowledge of Engineering	10	11,1%
	Technology learning	6	6,7%
	Designing	5	5,5%
	Total	90	100%
Negative Qualities	Unable to complete the activity	6	24%
	Long duration of activities	4	16%
	Difficulty of activities	4	16%
	Being unable to cooperate	5	20%
	Being unable to think creatively	5	20%
	Difficulty in designing	1	4%
	Total	25	100%

In the category of positive opinion in student interviews, the most frequently repeated code is willingness (f=10, 25.6%) followed by feeling of joy (f=9, 23.1%). In the code of willingness, participants explain it as S1 “Everyone in the group was very enthusiastic”; S8 “It was definitely impressive that we were very willing to design together.”: S17 stated that “mathematics can be made more willing by using science and technology”. Students belonging to the category of “feeling of joy”, S7 explains as “We have fun and learn as a group.”; S13 “I enjoyed this activity a lot.”, and S15 “It is very entertaining compared to other lessons.”

In the 21st century skills category, the most frequently repeated code is “Collaboration” (f=32, 35.9%), and followed “by problem solving skills” (f=13, 14.6%). Students explain it in the cooperation code as “We listened to each other's ideas in the group, and everyone was respectful to each other” (S10) and “Teamwork was effective. We exchanged ideas about what to do to solve the problem.” (S16), and “Mathematics can be made more willing by using science and technology.” (S12). In the problem-solving skill code, students state their opinions as "We saw that we can overcome the problems.” (S4), and "Because we thought to solve the problem and used our creativity to make the product." (S18).

In the learning category, the most frequently repeated code was “effective learning” (f=19, 21.2%). The codes that come after it are active participation (f=18, 20%), engineering knowledge (f=10, 11.1%), mathematics learning (f=9, 10%), interdisciplinarity (f=9, 10%), and science learning (f=5, 5.5%). Students' opinions on the effective learning code are explained as “If we try the subjects in other lessons, it will be more effective and permanent.” (S20); “because learning is stronger than other lessons. Besides, we learn better by doing something.” (S16); opinions on the active participation code as “It is very nice to try whether our design will work or not. We saw the mistakes by testing the product we made.” (S10), “Students are at the forefront of the system. We were quite active.” (S11); opinions on engineering knowledge “We even added technology to the course and learned how engineering is done.” (S21), “I had no interest in engineering.

With these activities, I understood what engineering means and it started to interest me.” (S13); views on mathematics learning as “We also realized where mathematics and science are used in real life.” (S7), “For example, I learned angles in Tinkercad. Angles and features of geometric shapes are important in designing” (S15), and codes for science learning as “Committing science and mathematics together became a very interesting and meaningful lesson when we added a more effective way of teaching and technology.” (S9).

The most frequently repeated codes in the negative qualities category are the codes of being unable to complete the activity (f=6, 24%), then being unable to cooperate (f=5, 20%), and being unable to think creatively (f=5, 20%). For the code of being unable to complete the activity, a student explains it as "Our design has not been completed. I think we didn't use the time well." (S5); for the code of being unable to cooperate it was stated that "First we had difficulties in establishing group unity with friends. Everyone wanted their own suggestion." (S3); for the code of being unable to think creatively "I had difficulty thinking. It was difficult for me to think and create." (S14).

Discussion

The findings of the research reveal that there is a statistically significant difference in gifted students' STEM attitudes in favor of the post-test. This finding shows that STEM activities positively affected gifted students' overall STEM attitudes and attitudes in sub-dimensions (mathematics, science, engineering and 21st century skills). There are many study findings that support this result (Kurt, 2019; Bircan & Köksal, 2020; Varol, 2020; Kalik & Kırındı, 2022). By its part, Şahin, Ayar and Adıgüzel (2014), Özçelik and Akgündüz (2017) and Ceylan, Ermiş and Yıldız (2018) stated that STEM activities increase students' attitudes towards STEM and develop their skills while Yamak, Bulut, and Dündar (2014) state that students develop their attitudes towards science and their scientific process skills through such activities.

In parallel with the increase in the STEM attitudes of the students, it is seen that there is an increase in the average STEM achievement scores of the students. It can be stated that the high STEM attitudes and the fact that they are more talented compared to their peers have an effect on the increasing continuation of the STEM success of gifted students throughout the application. Qualitative findings including the views of students on STEM practice support this result also. Opinions of gifted students on STEM were evaluated under four categories, namely "21st century skills, positive opinions about STEM, negative opinions about STEM and learning" (Bircan & Köksal, 2020; Varol, 2020).

The participants perceived STEM activities as an application that supports effective learning, enables active participation, allows learning by doing and can integrate the acquired knowledge into real life. While students want STEM activities to be reflected in their lessons in their schools, they also think that the lessons that take place in this way are effective, fun and motivating. Similar to this finding, Kim, Roh and Cho (2016) argue that gifted students do not consider mathematics and science concepts separately and solve problems creatively with an integrated teaching. Naizer, Hawthorne and Henley (2014) concluded that gifted secondary school students who participated in STEM courses increased their interest in mathematics, problem solving and technology, and their self-confidence in these areas. In line with these views, we can conclude that the positive views of gifted students have positively affected their STEM attitudes, and accordingly, there has been an increase in their academic achievement in STEM.

On the other hand, according to the effect value (d) analysis made on the difference between the pre-test and post-test average scores of SAS, it is seen that the applied STEM activities have a low-level effect on increasing the STEM attitude of gifted students. Considering the SAS attitude average scores, it was seen that the mean scores of the 5th grade students (0.598) were lower than the average scores of the 6th grade (0.655) and 7th grade students (0.652). In parallel with this finding, it has been determined that the average score of STEM achievement obtained from SAR for the 5th grade is lower than the average scores of the 6th and the 7th grades. It was seen that there were some negative opinions about STEM. Students could not complete STEM activities in the first activity and had time problems. They found the design phase difficult and had a little problem in cooperating. Therefore, the negative opinions of 5th grade students about STEM might have caused a decrease in their STEM achievement average score and in this case they negatively affected the students' STEM attitude.

In the study, it was concluded that the SAS scores of the gifted students did not differ significantly according to the gender variable. There are findings supporting this result in the literature. Kırıktaş and Şahin (2019), Aydın et al. (2017) and Köksal and Bircan, (2020) found that students' STEM attitudes do not differ significantly by gender. However, it was observed that female students achieved higher scores than male students in both STEM attitude scores and sub-dimensions of mathematics, science, engineering-technology and twenty-first century learning. Ceylan et al. (2019) found in their study that the STEM attitude scores of gifted female students were higher than male students but did not show a significant difference. Karakaya and Avgın (2016), in their study with normal students, found that female students' attitudes towards STEM were higher than that of boys.

The most interesting result obtained from this study is that while there is no significant difference between the pretest and posttest scores in the mathematics, science, and 21st century skills sub-dimensions of SBL according to gender, there is a significant difference in favor of female students in the engineering and technology sub-dimensions. A similar finding to this was argued by Köse, Kurtuluş and Bilen (2020) who found that while there was no significant difference in the STEM attitude scores of students except for engineering and technology dimensions, in which the attitudes of female students were higher than that of males.

In the current study, the engineering sub-dimension attitudes of female students are higher than males, which can be explained by the fact that STEM application is not applied like school lessons and the activities are chosen for both boys and girls. In the current study, some female students stated that they wanted science lessons at school to be taught with STEM activities like in the Science and Art Center, which is an out-of-school education place, and that the lessons taught in this way were enjoyable, entertaining, motivating, and instructive. Supporting this finding, Frenzel, et al. (2010) stated in their study that female students' interest in STEM decreased in STEM classes taught at schools. Gökbayrak and Karışan (2017) stated that the participants wanted science lessons to be taught with STEM activities, and that the lessons taught in this way were instructive, motivating and mind-enhancing.

In today's world, developments in engineering and technology are among the most important factors in the economic race of countries. The development of countries in the field of STEM should not be imposed only on male students. For this reason, the attitudes of young people who shape the future of countries, especially gifted students, should be developed in a positive way in the field of STEM. For this purpose, countries should support the development of STEM education programs that can be of interest not only to boys but also to girls, without worrying about grades at school or outside of school. Haussler and Hoffman (2002) found that female students increased their interest in science and their success with the changes in the curriculum.

As another result of the study, it was concluded that gifted students' STEM attitudes did not differ according to the grade level. In a study like this, Bircan and Köksal (2020) concluded that students' STEM attitude scores do not differ significantly according to grade level. In STEM activities, it was seen that the average scores of gifted students from STEM activities according to their grade level were very close to each other, and it was determined that the most successful class was the 6^{th} grade. Some studies in the literature have revealed that STEM attitudes decrease from lower classes to upper classes (Lamb, Akmal, & Petrie 2015; Unfried, et al., 2015). Contrary to this, some studies indicate that attitudes towards science do not decrease as students enter secondary school (DeWitt, Archer & Osborne, 2014). Considering that the 6^{th} and 7^{th} grade students have more positive views on STEM activities than the 5th grade students, it explains the fact that the STEM attitudes of the 5th grade students are slightly lower than the other grades.

Bringing STEM attitudes to a positive level from an early age will increase the success of the student in STEM fields in the future and will encourage them to choose a career in STEM fields. Heilbronner (2011) stated that gifted male and female students' beliefs in their ability to be successful in STEM emerged as an important factor in determining whether individuals remained in STEM fields. Wang, Eccless, and Kenny (2013) found in their study that female students are still less likely to choose a STEM major or profession, even if they have similar or higher levels of achievement than males. This situation shows us that the success in STEM courses (high grades) alone is not enough for students to turn to STEM fields, and the STEM attitude of the students should be positive.

For this reason, as it is seen in the study, STEM programs that can attract the attention of girls and boys should be applied in order for gifted students to achieve success in STEM fields. Out-of-school STEM learning opportunities such as science and arts centers should be provided for gifted students to receive richer STEM education. Steenbergen-Hu & Olszewski-Kubilius (2017) stated that there is a need for complementary, enriched and accelerated STEM learning programs to serve gifted students inside or outside of regular schools. In order to meet this need, STEM education programs should be prepared for different levels. In line with this information, the following suggestions can be made:

1- It can be recommended to increase the number of studies investigating STEM attitudes and STEM career interests of gifted students.

2- It may be recommended to conduct studies investigating the factors underlying the attitudes of gifted students towards mathematics, science, engineering, and technology.

3- In this study, an engineering-based STEM education was carried out. In other studies, STEM education applications can be carried out by changing the weights of some disciplines.

4- It can be recommended to conduct research that include teaching programs and activities to further increase the STEM attitude levels of gifted students.

5- This research is limited to secondary school students diagnosed as gifted/special talent, students' opinions and applied activities. In other studies, studies can be conducted to examine the STEM attitudes of gifted or non-gifted students at different levels.

Conclusion

It has been determined that STEM develops 21st century skills, provides effective learning, and is an approach that develops positive attitudes such as increasing desire, self-confidence and interest considering that STEM activities positively affected gifted students' overall STEM attitudes and attitudes in sub-dimensions (mathematics, science, engineering and 21st century skills), their success in the STEM field, and the data of interviews with students at the end of the application.

In the study, it was concluded that the SAS scores of the gifted students did not differ significantly according to the gender variable. While there was no significant difference according to gender in the mathematics, science and 21st century skills sub-dimensions of SAS, there was a significant difference in favor of female students in the sub-dimension of engineering and technology. As another result of the study, it was concluded that gifted students' STEM attitudes did not differ according to grade level.

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