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Özel Yetenekli Ortaokul Öğrencilerinin Eğitiminde FeTeMM Yaklaşımına Dayalı Bir Öğretim Tasarımının Öğretim Sürecine Etkileri*

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Makale Bilgisi	ÖZET
Geliş Tarihi: 03.07.2019 *Kabul Tarihi*: 11.08.2020 *Erken Görünüm Tarihi*: 20.08.2020 *Basım Tarihi*: 31.01.2022	Çalışmanın amacı, özel yetenekli öğrencilerin eğitiminde kullanılabilecek FeTeMM yaklaşımına uygun olarak geliştirilen bir öğretim tasarımının öğretim sürecine etkilerinin incelenmesidir. Araştırmada kullanılan desen, karma yöntem araştırma desenlerinden gömülü deneysel desendir. Çalışmada, deney grubunda 9 kız, 12 erkek; kontrol grubunda 8 kız 12 erkek olmak üzere 5-6-7-8. Sınıfta öğrenim gören 41 özel yetenekli öğrenciyle çalışılmıştır ve öğrenciler tipik durum örnekleme yöntemine uygun olarak belirlenmiştir. Deney grubunda, FeTeMM yaklaşımına uygun olarak hazırlanan öğretim tasarımı, kontrol grubunda BİLSEM'lerdeki (Bilim ve Sanat Merkezlerindeki) standart etkinlikler uygulanmıştır. Nicel veriler; Ayverdi (2018) tarafından geliştirilen Bağlam Temelli Bilimsel Yaratıcılık Testi (BTBYT) ile toplanmış ve tekrarlı ölçümler için iki faktörlü ANOVA testi ile SPSS 22 Paket Programı kullanılarak analiz edilmiştir. Nitel veriler; gözlem ve görüşme formları ile toplanmış ve Nvivo 11 programı ile analiz edilmiştir. FeTeMM yaklaşımına dayalı öğretim tasarımının uygulanması sonucunda BTBYT puanları açısından deney ve kontrol grupları arasında istatistiksel olarak anlamlı bir fark oluşmuştur. FeTeMM yaklaşımına dayalı öğretim tasarımı öğrencilerin bilimsel yaratıcılıklarının gelişmesini sağlamıştır.Nitel bulgular; mühendislik becerileri ve bilimsel süreç becerilerinin süreç boyunca deney grubunda kontrole göre daha fazla kullanıldığı ve daha fazla gelişim gösterdiğini ortaya çıkarmıştır. Sonuçlar doğrultusunda, FeTeMM etkinliklerinin BİLSEM etkinlik kitaplarının bu türden etkinlikleri daha çok içerecek şekilde zenginleştirilmesi önerilebilir. **Keywords:** FeTeMM yaklaşımı, özel yetenek, bilimsel yaratıcılık, mühendislik becerileri, bilimsel süreç becerileri

The Effects of Instructional Design Based on the STEM Approach on the Teaching Process of Training of Gifted Secondary School Students

Article Information	ABSTRACT
Received: 03.07.2019 *Accepted*: 11.08.2020 *Online First*: 20.08.2020 *Published*: 31.01.2022	The purpose of the study is to examine the effects of an instructional design developed in compliance with the STEM approach, which can be used to educate gifted students on the teaching process. The pattern used in the research is the embedded experimental model which is among the mixed-method research patterns. Within the study, it has been worked with 41 gifted students from 5th, 6th, 7th, 8th grades in which the experimental group included 9 female, 12 male students; and the control group had 8 female and 12 male students and these students were selected based on typical case sampling. In the experimental group, the instructional design according to the STEM approach has been applied and in the control group, the standard SAC (Science and Art Center) activities have been used. The quantitative data have been gathered with the Context-Based Scientific Creativity Test (CBSCT) and have been analyzed via Two-Way ANOVA Test for Repeated Measures by using SPSS 22 Package Program. The qualitative data have been gathered by observation and interview forms and analyzed by the Nvivo 11 program. As a result of the instruction design application based on the STEM approach, there has been a statistically significant difference between the experimental group and the control group. Instructional design based on the STEM approach has enabled students' scientific creativity to develop. The qualitative findings have shown that during the process engineering skills and scientific process skills have been utilized and developed more in the experimental group compared to the control group. Based on results, it can be suggested to enrich SAC (Science and Art Center) activity books by using these kinds of STEM activities more. **Keywords:** STEM approach, gifted, scientific creativity, engineering skills, scientific process skills.

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1. INTRODUCTION

Gifted students are the students who see and make sense of the world differently than their peers and show an advanced performance in different talent areas. According to the Marland Report (1972), the gifted individuals are the ones who show superior performance than their peers in the fields of general cognitive skills, special academic talent, visual or performance-based artistic talent, creativity, leadership, and psychomotor skills. As can be seen in the definition, gifted individuals have higher performance in different skill areas than their peers and their educational needs are different from their peers. Their differentiated and advanced interest areas and talents compared to their peers reveal a need for different education.

To meet gifted individuals' needs for a different education the methods like acceleration, grouping, and enrichment are realized (Bildiren, 2013; Gür, 2017; Öznacar and Bildiren, 2012). In Turkey, Science and Art Centers (SAC) are among the institutions in which temporary grouping is practiced (Ataman, 2004). Within such schools, differentiation and enrichment activities are conducted as per the interests, skills, and potentials of the students. (MEB, 2016a). One of the approaches which can be used in SAC during the enrichment activities is the STEM approach. The STEM approach offers a rich learning environment where students can be active and a differentiated education understanding. In the context of gifted students presenting education with the STEM approach is important in terms of providing a student-centered environment focusing on higher order thinking skills and appealing to students' interests and talents.

The STEM approach is an integrated approach in which science, engineering, and mathematics disciplines are handled together (Bybee, 2010). The STEM approach in most countries is the integration of engineering to science, technology, and mathematics. Integrating engineering to education is found beneficial since it increases learning and success in science and mathematics, awareness about engineering and the works of engineers, develops engineering design understanding and skills in students, sustains interest in engineering as a career and increases technological literacy (Katehi, Pearson and Feder, 2009).

Enjoying learning, analytical thinking, problem-solving, creative and critical thinking, high career goals, ability to work both independently and collaboratively, using mathematics and sciences to solve problems are common characteristics of both engineers and gifted students (Mann, Mann, Strutz, Duncan ve Yoon, 2011). The fact that they have many common characteristics makes us think that using engineering in the education of gifted students can result in positive outcomes (Olszewski-Kubilius, 2009). In the literature, it is possible to encounter the studies reporting the outcomes of the STEM practices performed by different institutes and persons. There are examples of research studies analyzing the effects of the STEM practices realized with gifted students on students' interest (Almarode, Subotnik, Crowe, Tai, Lee and Nowlin, 2014; Burt, 2014; Okulu, 2019), self-efficacy (Almarode, Subotnik, Crowe, Tai, Lee ve Nowlin, 2014; Burt, 2014) in science, mathematics and/or technology, their academic success (Kim, Cross and Cross; Okulu, 2019; 2017; Young, Young and Ford, 2017), their positive experiences related to science and math activities (Ihrig, Lane, Mahatmya and Assouline, 2018; Öztürk, Bozkurt-Aslan ve Tan, 2019), their scientific process skills (Barış ve Ecevit, 2019; Cotabish, Robinson, Dailey ve Hughes 2013; Robinson, Dailey, Hughes and Cotabish, 2014; Öztürk, Bozkurt-Aslan and Tan, 2019), content and concept knowledge (Cotabish, Robinson, Dailey and Hughes 2013; Robinson, Dailey, Hughes and Cotabish, 2014), their self-confidence and career knowledge (Dieker, Grillo and Ramlakhan, 2012; Willis, 2017), 21st century skills (Abdurrahman, Ariyani, Maulina ve Nurulsari, 2019; Bulut, 2019; Özçelik and Akgündüz, 2018) and creative problem solving skills, attitudes (Kim and Choi, 2012), attitudes towards science, cooperation skills (Barış and Ecevit, 2019; Wilson, 2018), engineering and design skills (Öztürk, Bozkurt-Aslan and Tan, 2019), learning with collaboration skills (Seren, 2019), scientific research/product design skills, scientific writing skills (Bodur, 2019).

Scientific creativity can be defined as producing original and useful ideas and/or products (Sak and Ayas, 2013) (A large number of factors that influence scientific innovation can be discussed. In the framework of this study, however, particular emphasis was placed on scientific process skills and engineering skills in conjunction with STEM.). To produce useful and original products in science research methods and tools should be used. These methods and tools constitute the scientific process skills (SPS). While scientists are making research and analyses, and teachers are teaching science courses in a meaningful way, they should use the SPS. The students also should use the scientific process skills to learn the world of science and technology in detail (Turiman, Omar, Daud and Osman, 2011). In the study comparing the components of creativity with SPS, Meador (2003) stated that the main SPSs such as observation, comparison, classification, and communication skills are related to creative thinking components of openness to experience, flexibility, and detailing. Flexibility and creative convergence are the creativity components that coincide with the inference and prediction skills which she calls mid-level SPS. Also expressed as resistance to early closure and creative convergence were creativity components that correspond to the setting of the hypothesis and the ability to control and define variables represented as advanced BSB. As can be seen from Meador's (2003) interpretations, there is a strong connection between scientific creativity and SPS. Therefore it is necessary to include practices to enhance SPS to promote scientific creativity. Laboratory studies are one of the main ways of developing SPS. However, rather than an interdisciplinary method, laboratory experiments rely on scientific research linked to one particular area. However, Üstündağ

(2009) and a large number of scientists stress that individuals of today need to have versatile skills to fulfill the needs of our age. This condition calls for interdisciplinary approaches like STEM.

Producing original products in science needs engineering skills as well. Within the STEM approach, students generate products by using engineering design processes. In the process of integrating engineering to education, teachers can use the engineering design process by motivating students to define and solve problems in the society and by providing a creative learning environment (Basham and Marino, 2013). Therefore, when creating an instructional design that suits the STEM approach, it is important to consider scientific creativity, scientific process skills, and the process and skills related to engineering. This study has vital importance from the point that it considered all these factors regarding creating the instruction design. Since, for the education of gifted students of SAC, an instructional design in which all these factors were taken into account was not included in the literature review. However, when MEB (2017) SAC (BILSEM) Science Framework Program is analyzed, it is found that only 6 out of 112 program activities seek to incorporate the STEM approach. Such practices are not activities that are designed according to a certain design, but they emphasize the interdisciplinary approach (Ayverdi, 2018). There is a need for programs designed in line with design principles and focused on improving the scientific creativity, scientific process skills, and engineering skills of the students for teachers who wish to implement this approach at SAC. Besides, considering that when teachers face a new approach they need examples to utilize with their students, it is expected that this study contributes to the literature by offering an example of the practice of the STEM approach which can be realized with gifted students.

1.1. Purpose of the Study

The purpose of the study is to examine the effects of an instructional design developed in compliance with the STEM approach, which can be used to educate gifted students on the teaching process.

1.2. Problem of the Study

What are the effects of an instructional design developed in compliance with the STEM approach, which can be used to educate gifted students on the teaching process?

12.1. Sub-problems of the study

1. Does the implemented instructional design influence the scores of gifted students in scientific creativity?

2. How do gifted students use their scientific process skills, and knowledge and skills related to engineering, according to the teacher's observations during the experimental process?

3. What are the opinions of gifted students regarding their scientific process skills and their knowledge and skills related to engineering before and after the implementation of the instructional design?

2. METHODOLOGY

2.1. Research Design

The pattern used in the research is the embedded experimental model which is among the mixed-method research patterns. The embedded experimental model is the pattern in which the experimental pattern is introduced as the study's key model and the qualitative data is embedded in the design of the experiment. (Creswell and Plano Clark, 2014). Within the experimental part, to analyze the effect of the practice in which the STEM approach is used on scientific creativity, the random pattern which is matched with pretest post-test and control group among the real experimental patterns is used (Büyüköztürk, et al., 2010). Within the qualitative part of the study, the change in students' engineering skills and scientific process skills has been analyzed based on observation. Also, the students' condition related to engineering skills and scientific process skills before and after the process has been revealed with interviews. In each group, the interviews were conducted with 3 students. The study pattern has been presented in Diagram 1.

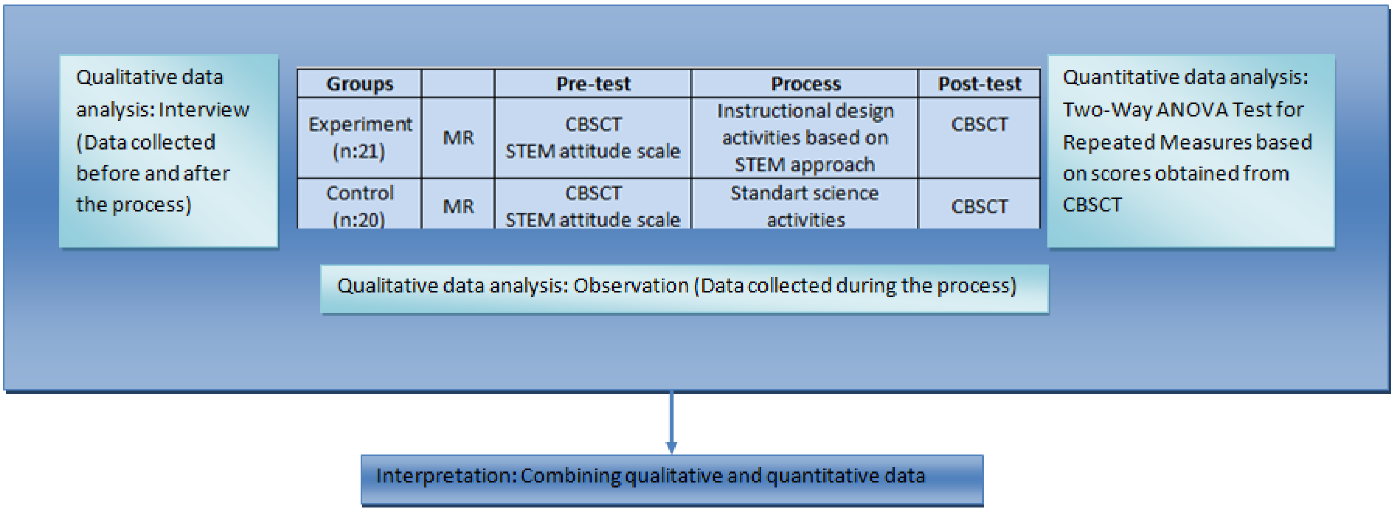

Diagram 1. Research process

2.2. Participants

The study group consists of secondary school students in 5th, 6th, 7th, 8th grades attending to SAC. The typical case sampling method, which is among the purposeful sampling methods, was used to determine the study group. The sampling method that works by selecting one of the many situations in the universe related to the research problem, is the typical case sampling. (Büyüköztürk and others, 2010).

To determine the study group, on the web page of a SAC in Marmara Region it has been announced that a study will be carried out during summer and worked with limited (42 students) people. Students are required to apply via the system. When the desired number was achieved, the application process through the system was closed. Among these 42 students matched subject design was formed according to the grades, genders, and STEM attitude scores. The matched subjects were placed randomly in two different groups and two equivalent groups of 21 students were obtained. One of the groups was randomly defined as the experimental group and the other as the control group randomly. One of the 8th-grade male students who were unable to attend all the activities was excluded from the study's scope. The information related to gender and school grade of the students in the study group is presented in Table 1 and Table 2:

Table 1.
The Distribution of the Study Group According to Gender

Groups	**Female**	**Male**	**Total**
Experiment	9	12	21
Control	8	12	20
Total	17	25	41

Table 2.
The Distribution of the Study Group According to the Class Grades

Groups	**5th grade**	**6th grade**	**7th grade**	**8th grade**	**Total**
Experiment	9	3	5	4	21
Control	9	2	6	3	20
Total	18	5	11	7	41

By reviewing Table 1 and Table 2 it is found that a total of 41 students were worked with, 21 in the experimental group, and 20 in the control group. During the qualitative data-gathering stage, 3 students were chosen from each group and semi-structured interviews were carried out before and after the practice. While determining the students, the maximum variation sampling method was used. Considering the students' STEM attitude scores, one student with a low score, one with average and one with high were chosen from each of the groups.

2.3. Data Gathering Instruments

The STEM attitude scale adapted by Yıldırım and Selvi (2015) was used before the application to ensure the equivalence of the groups when gathering the quantitative data from the study. The Context-Based Scientific Creativity Test (CBSCT) developed by Ayverdi (2018) was used as a pretest and posttest. Additionally, forms of observation and interviews (especially in gathering data on skills in scientific processes and engineering) were used to gather qualitative data.

2.3.1. Context-based scientific creativity test (CBSCT)

The Context-Based Scientific Creativity Test (CBSCT) was developed by Ayverdi (2018). To determine the scope validity of the CBSCT, an item table was prepared and presented to the expert opinion. For CBSCT, a list of 21 items was developed, consisting of open-ended questions. In compliance with the opinion of 5 experts, the Scope Validity Ratio (SVR) was determined and certain items were excluded from the scale and 7 items were finalized. The pilot study was conducted with 29 students of 2 different SACs. Item-total correlations of the scale are between .397 and .752. Item discrimination in 1 item is low and in other items it is high. The Cronbach Alpha reliability coefficient of CBSCT was calculated as 0.783. To assure the inter-rater reliability of the scale, it was scored by 2 different persons and determined that the correlation between the scorers according to the fluency, flexibility, and originality varied between .879 and .986.

2.3.2. STEM attitude scale

The STEM attitude scale was developed by Faber, Unfried, Wiebe, Corn, Townsend, and Collins (2013); and adapted by Yıldırım and Selvi (2015) in Turkish. The scale consists of four factors and it was determined that the Cronbach alpha values of its factors were between 0.86 and 0.89 and its adjusted item-total correlations varied between 0.38 and 0.78. It was determined that the Cronbach alpha reliability coefficients calculated with the data in our study varied between 0.89 and 0.92 and item-total correlations varied between 0.28 and 0.75.

2.3.3. The observation form and the interview form

To see the change in students' engineering skills and scientific process skills throughout the study, to consult their opinion, the interview and observation forms were created. The skills discussed in the classification for scientific process skills were incorporated in the STEM Education Report published by MEB (2016b). The advice of 3 experts was requested for the forms created and appropriate adjustments were made in the forms in compliance with their recommendations.

In the study, an observation study structured in line with the determined coding system was carried out using the observation form. The study included two observers. The same observers are teachers and have a postgraduate education. The same observers (for example, the person who made the observations in the context of Space Research is the 1st observer in the experimental group and the control group as well) present in both groups. The researchers carried out the activities, the observers observed the students in this process and got the necessary notes. The interview form was used while conducting the semi-structured interviews with 3 students from both the experiment and control group before and after the study. The duration of the interviews was approximately 15-20 minutes.

To ensure the validity of the observation study, it was ensured that the observer stayed in the environment together with the trainer who performed the applications during the activity, and therefore, validity was attempted to be provided by long-term interaction with the participants. To ensure the observation's reliability, video recording was taken during the process, and another researcher reviewed and checked the video recordings and the observer notes. For the validity of the interviews, the document was read and checked by the student interviewed after the interviews were transcribed. Two coders examined the data obtained from the interviews for the reliability of the interviews, and a consensus was reached through discussion of the hesitation points.

2.4. Constitution of the Instructional Design

The instructional design used in the study was constituted following the general instructional design. This model includes the analysis, development, practice, and evaluation stages (Ocak, 2015; Akkoyunlu, Altun, and Yılmaz-Soylu, 2008). The instructional design was generated and implemented in a setting wherein the students in the experimental group were together, in line with the contexts defined in conjunction with those phases. The accomplishments in the science curriculum and framework program were analyzed for the teaching in the established contexts, and other high-level achievements were introduced to improve them. The achievements related to the STEM fields technology, engineering, mathematics, and 21st-century skills were developed by collaborating with relevant experts in the field and examining the curriculum achievements. In the control group, before the enrichment of the acquisitions, existing standard science activities were used (some of these activities in the control group were included in the activity book developed for SACs, and some were put into practice by one of the SAC researchers since the period before the activity book was developed. As it seeks to provide students with education according to their skills, after the activity book is created, various activities outside of the book are included in the process as well).

The accomplishments linked to scientific creativity were used to attract attention and assess the preliminary information in the instructional design planned for the experimental group as per the 5E model. In the deepening phase, directions were rendered toward providing scientific creativity in the products produced by the students. While utilized in many parts of 5E, the stages of intro and deepening are structured primarily for the usage and development of scientific creativity. Scientific method competencies are designed to be included in the discovery phase during the experimental studies carried out. The part of STEM is planned to be used in the deepening phase specifically for an engineering study. Evaluation for content, process, and product was performed. The experimental and control groups performed an application of 56 hours.

3. FINDINGS

In this mixed-method study performed to show the results (scientific creativity, scientific process skills, engineering knowledge, and skills) of an instructional design built in conjunction with the STEM methodology, which can be included in the education of gifted students, quantitative and qualitative findings were evaluated independently and merged in the interpretation phase.

3.1. The Instructional Design's Effects on Students' Scientific Creativity

To determine if the instruction design was effective on students' scientific creativity, the Two-way ANOVA for Repeated Measures test was conducted. When the assumptions required for the application of the two-factor ANOVA test for repeated measures were examined, it was observed that the first assumption should show a normal in the distribution of the data with a minimum interval scale in each cell of the averages to be compared. The Shapiro-Wilk test in which both the pretest and posttest data had a normal distribution were analyzed with histogram, Q-Q plot, box plot and it was determined that the data have a normal distribution. The second assumption is that the variances of the groups to be compared by their mean are homogeneous. To analyze the homogeneity of the variances the Levene test was conducted and the results are presented in Table 5. When Table 3 is examined it is seen that the variance homogeneity for the CBSCT in experiment and control groups is assured (p>.05).

Table 3.
The Leven Statistics of the Variance Homogeneity of The Groups' Pretest and Posttest Measurements For The CBSCT

N	Measurement	Sd1	Sd2	F	p
41	Pretest	1	39	.227	.637
41	Posttest	1	39	.137	.713

For the binary combinations of the measurement groups, to see if there is a significant difference between the groups' covariances, they were analyzed with the Box's M test and it is shown in Table 4.

Table 4.
The Box's M Test Related to the Groups' Pretest Measurements Covariance Equality

N	Box's M	Sd1	Sd2	F	p
41	.222	3	298395.318	.070	.976

When Table 4 is examined it is seen that the groups' covariances for the CBSCT are equal (Box's M= .222, (F(3, 298395.318) = .070, p >.05). For the CBSCT, it is seen that to be able to conduct two-way Anova for the repeated measures the necessary assumptions were provided. Before the two-way ANOVA statistics for the repeated measures were applied, the descriptive values were presented in Table 5.

Table 5.
The Descriptive Values Related to the Experiment and Control Groups' CBSCT Pretest and Posttest Scores

Groups	CBSCT Measurements	n	$\underline{X}$	SD
Experiment	Pretest	21	30.76	16.23
	Posttest	21	52.05	15.79
Control	Pretest	20	29.30	15.87
	Posttest	20	29.65	16.64

When Table 5 is examined it is seen that the experiment group's pretest score mean is 30.76 and its posttest mean is 52.05. The control group's pretest score mean is 29.30 and its posttest mean is 29.65. To determine if the differences seen in the scores were statistically significant, the two-way ANOVA test for the repeated measures was conducted and it is presented in Table 6.

Table 6.
The Two-Way ANOVA Findings for the Repetitive Measurements Related to the Experiment and Control Groups' CBSCT Pretest and Posttest Scores

The Source of the Variance	SS	Fv	MS	F	p	η²
Intergroup	19646.902	40	3344.81			
Group (Experiment/Control)	2915.808	1	2915.808	6.797	.013	.148
Error	16731.094	39	429.002			
Intergroup	8212.997	41	4734.128	26.189	.000	.402
Test (Pretest and Posttest)	2397.607	1	2397.607			
Group*Test	2244.972	1	2244.972			
Error	3570.418	39	91.549	24.522	.000	.386
Total	27859.899	81	8078.938			

When Table 6 is examined, according to the two-way ANOVA findings obtained on the experiment and control group students' pretest and posttest scores related to the CBSCT, it can be said that the group effect is significant and largely effective ($F_{(1,39)}$=6.797; p<.05, η^2=.148). The Eta-squared values for .01 imply low effect, for .06 medium effect, and for .14 large effect (Cohen, 1988). Without differentiating pretest and posttest, there is a statistically significant difference between the mean scores related to the CBSCT of the experiment and control groups.

It has been understood that the effect of the CBSCT conducted at different times is significant and largely effective ($F_{(1,39)}$=26.189; p<.05, η^2=.402). Without making a distinction between the experiment and control groups there is a statistically significant difference between the posttest scores and pretest scores. Besides, when the group-test mutual influence is analyzed, it is seen that the score increase in the experiment group where the instruction design is practiced is higher than the score increase in the control group in a statistically significant level ($F_{(1,39)}$=24.522; p<.05, η^2=.386). When the Eta-squared value is examined, it is understood that the group and test mutual effect has a high effect size. In that case, it can be said that the instruction design has a significant effect on scientific creativity.

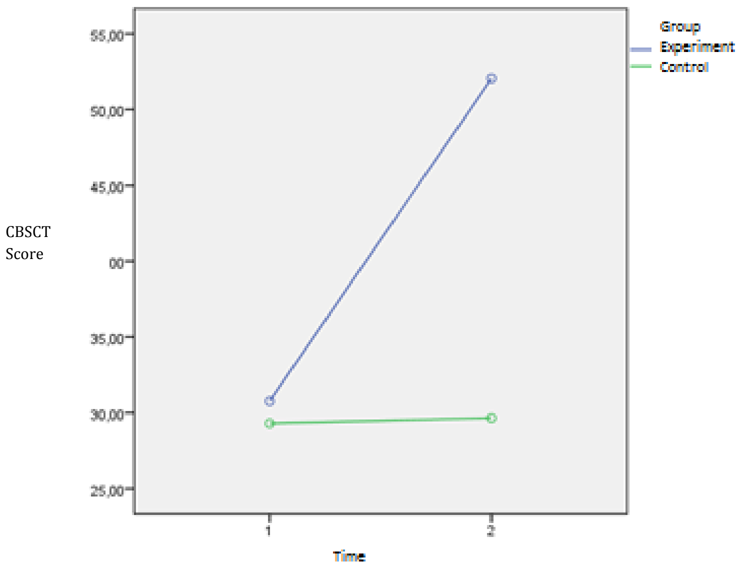

Diagram 2. The diagram of the experiment and control groups' mean scores of pretest and posttest related to the CBSCT

When Diagram 1 is examined, it is seen that there is an apparent difference between the CBSCT posttest scores of the experiment group and the scores of the control group and the experiment group's posttest score is higher than the control group's posttest mean score. Although there is an increase in the mean score of each group, it can be said that the increase in the experiment group's mean score is quite higher than the increase in the control group.

3.2. The Change in Students' Scientific Process Skills and Their Knowledge and Skills Related to Engineering during the Practice of the Instruction Design

Within the study, the change in students' knowledge and skills related to engineering and scientific process skills was analyzed through the data gathered with observation and interview forms. The experiment and control groups' level of using their scientific process skills during the practice based on observation data is presented in Table 7:

Table 7.
Findings Related to Experiment and Control Groups' Using Scientific Process Skills along the Process

SPS Type	Scientific process skills	Experiment Group Frequency (f)	Control Group Frequency (f)
Basic scientific process skills	Observing	189	77
	Measuring	183	77
	Classifying	54	36
	Recording data	84	12
	Making number and space relations	31	9
	Communicating	133	122
Experiment confirmation scientific process skills	Predicting	35	11
	Determining variables	14	9
	Defining operationally	40	14
	Inferring	20	11
Designing and applying authentic experiment scientific process skills	Formulating hypotheses	6	3
	Constructing experiment	4	0
	Changing and controlling variables	12	2
	Using data and modeling	42	0
	Decision making	9	0

When Table 7 is examined, it is seen that the students in the experiment group use their scientific process skills more frequently than the students in the control group. In both groups, the basic scientific process skills were used more compared to the experiment confirmation and design of authentic experiment scientific process skills. The findings related to the groups' usage of engineering skills are presented in Table 8.

Table 8.
Findings related to the usage of engineering skills by the experiment and control groups throughout the process

Engineering skills	Experiment Group Frequency (f)	Control Group Frequency (f)
Measuring	141	74
Data gathering	104	6
Recording data	49	9
Data evaluation	58	3
Estimation	20	11
Knowledge related to engineering branches	5	1
Knowledge related to engineering	32	2
Analyzing the problem	90	1
Sensitivity in measurement	26	0
Application of mathematical formulas	1	0
Planning	85	6
Developing prototypes	115	0
Design handling	74	1
Quality control	27	0
Reporting	40	0
Teamwork	168	19
Describing and analyzing the instructions	83	0
Modeling and making simulation	47	0
Abstraction	1	0
Establishing mathematics-computer connection	5	0

When Table 8 is examined, it is seen that the experimental group used the engineering skills more than the control group. The skills like prototyping, modeling, and making simulations that are used excessively in engineering works were used by the experiment group much more.

3.3. Findings Obtained by the Semi-Structured Interviews

The data obtained from the semi-structured interviews conducted before and after the practice of the instruction design with 3 students from both the experiment and the control group were analyzed via the Nvivo program and are presented in the diagrams 3,4,5,6:

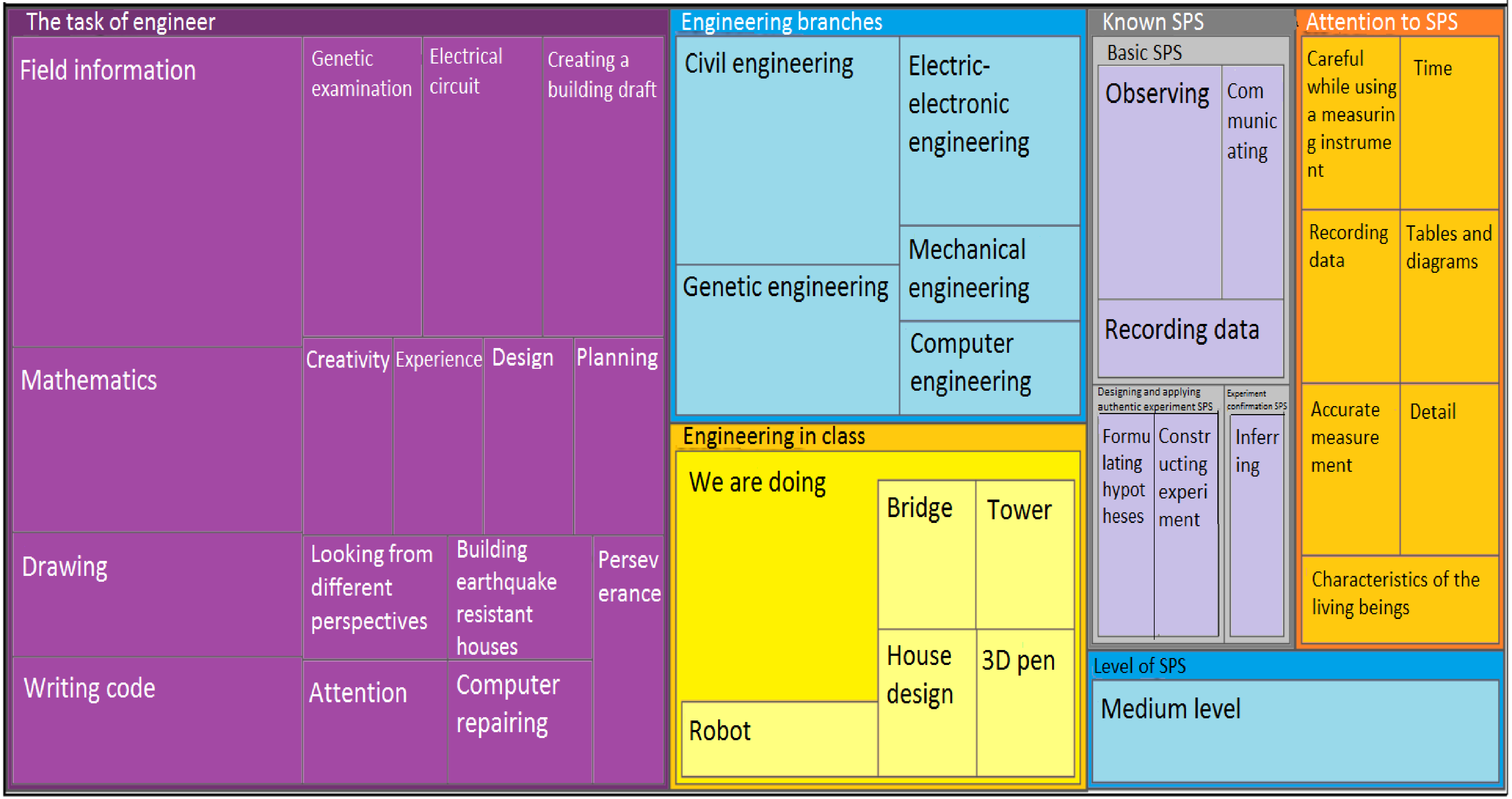

Diagram 3. The hierarchical diagram obtained from the coding of the pre-interviews conducted with the experimental group

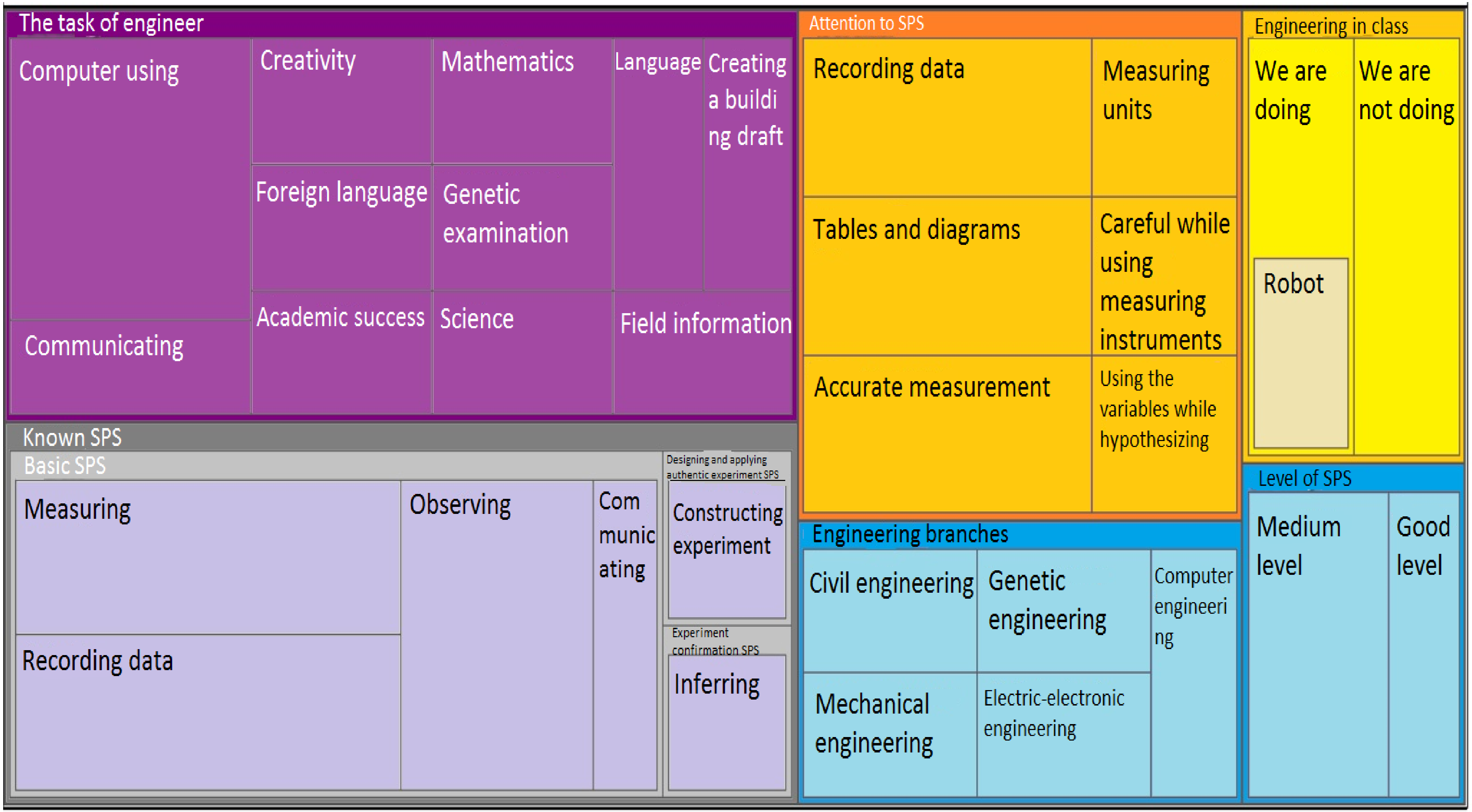

Diagram 4. The hierarchical diagram obtained from the coding of the pre-interviews conducted with the control group

When Diagram 3 is analyzed it is seen that the 3 students from the experiment group stated the skills and tasks that an engineer had to have as field information, drawing, mathematics, and coding. Creating a building draft, genetic examination, creativity, wiring, experience, looking from different perspectives, design, planning, attention, building earthquake-resistant houses, perseverance and computer repairing are also the emphasized subjects. The student 2 from the experiment group (E2) stated the fact that an engineer had to have field information as follows: "S/he has to be informed on the field in which s/he works." The engineering branches that 3 of the experimental group students emphasized during the pre-interviews were genetic engineering, civil engineering, mechanical engineering, electric- electronic engineering, and computer engineering. When they were asked if they make engineering studies in Science lessons, all three of the students answered that they did and stated Bridge, Tower, and House design as examples. Besides that, they stated "Robot" activities as engineering activity examples. In addition to this, one of the students mentioned a design work he made with a 3D pen outside SAC.

3 of the experimental group students mentioned recording data, observing and communicating from the basic scientific process skills; they mentioned inferring from the experiment confirmation scientific process skills and they mentioned experiment setup and hypothesizing from the designing authentic experiment scientific process skills. About hypothesizing from the designing authentic experiment scientific process skills, the E2 said "Firstly I do research, write down hypotheses. Then I make experiments." When they were asked about which details they pay attention when they use their scientific process skills, they stated that they acted time punctual, they were careful while using a measuring instrument, they recorded the data and tried to transform them into tables and diagrams, they were attentive to measure correctly, they paid attention to details and they were careful about the characteristics of the living beings. All three of the students stated that they used their scientific process skills at a moderate level.

Diagram 4 shows the hierarchical diagram obtained by coding the pre-interviews conducted with the control group. In the diagram when the 3 control group students thought about the skills and tasks that the engineer had to have been examined, it is seen that they mentioned communicating, computer use, academic success, creativity, foreign language, genetic examination, field information, mathematics, science, language, and creating a building draft. The opinion suggesting that an engineer had to be creative was expressed by one student each in the experimental group and the control group pre-interviews. The student 2 (C2) from the control group said: "An engineer has to be creative. Thinking about something and produces something that does not exist before requires to be creative." During the pre-interviews, the engineering branches mentioned by three students from the control group are genetic engineering, civil engineering, electric-electronic engineering, and mechanical engineering. The students who said that they have activities in which they use engineering only mentioned robot studies.

The control group students mentioned recording data, observing, and communicating skills from the basic scientific process skills, but they also mentioned the measuring skill as different from the experiment group. From the experiment confirmation skills, they mentioned inferring, and from the designing authentic experiment scientific process skills, they mentioned only experiment setup. Hypothesizing skill from the designing authentic experiment scientific process skills is a skill which was present in the experiment group but wasn't revealed in the control group., The C2 who mentions experiment confirmation scientific process skills emphasizes inferring scientific process skill by saying "I interpret the results of the experiment." When the control group students are asked about to which details they paid attention while using scientific process skills, some students said that they paid attention to recording data and measuring units, they recorded data by using tables and diagrams, they acted carefully while using measuring instruments, they paid attention to measuring correctly and they tried to use the variables while hypothesizing. When they were asked about at which level they used the scientific process skills, two of the students said that they used SPS at a moderate level and one of them said that they used it at a good level.

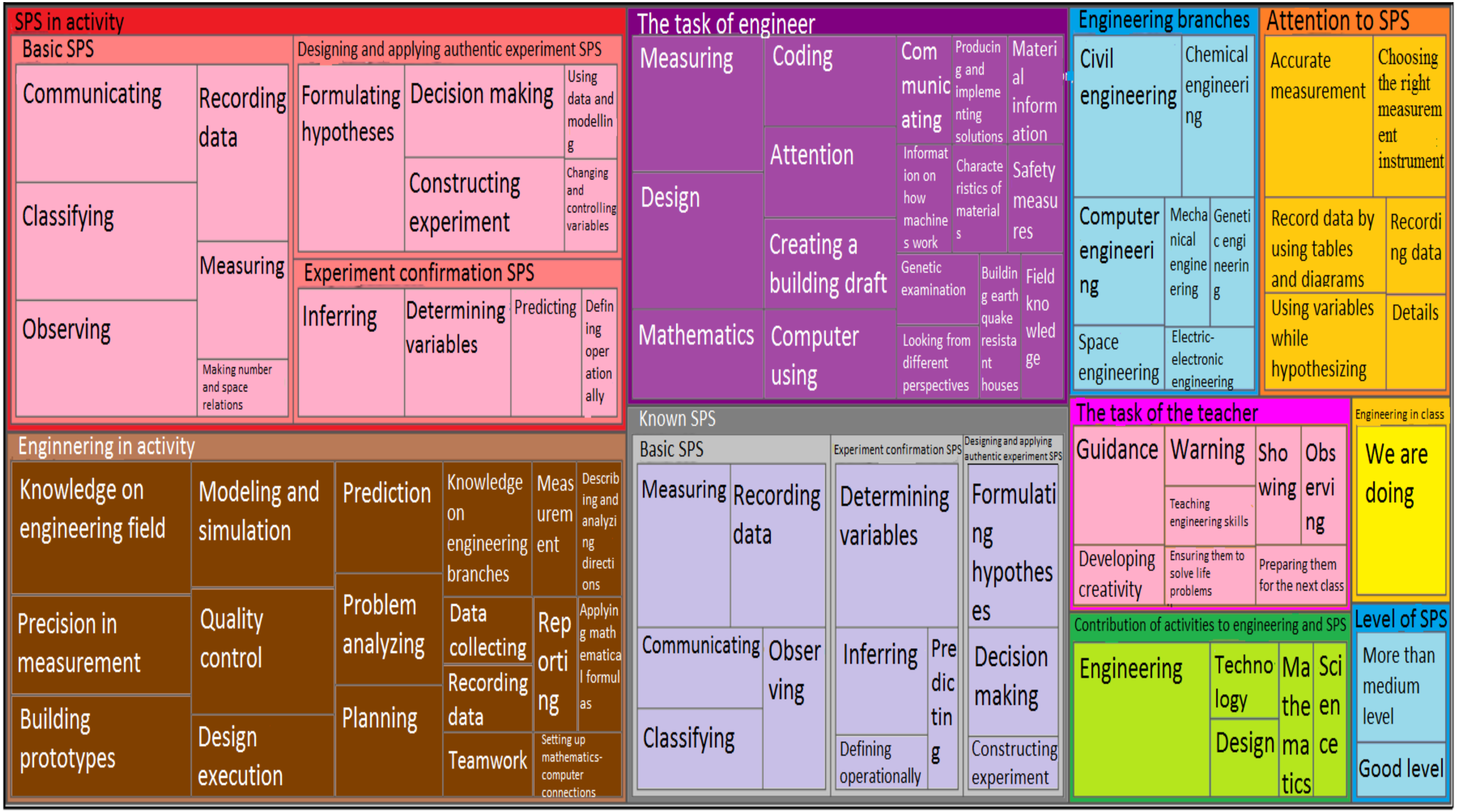

Diagram 5. The hierarchical diagram obtained from the coding of the final interviews conducted with the experimental group

Diagram 5 shows the hierarchical diagram obtained by coding the experiment group's final interviews. In the diagram when the 3 student thoughts from experiment group on the engineer's tasks and the skills he/she has to have been examined, it is seen that they emphasize measuring, design, mathematics, coding, attention skill, creating a building draft, computer using, communicating, producing and implementing solutions, material information, information on how machines work, characteristics of materials, safety measures, genetic examination, looking from different perspectives, building earthquake-resistant houses and field knowledge. For example, the required skill of an engineer is producing, and implementing solutions was expressed by E3 as "S/he produces solutions for the problems in the world and chooses the optimal solution. Then s/he puts the optimum solution into action." The engineering branches that the 3 students from the experiment group emphasized during the final interviews are civil engineering, chemical engineering, computer engineering, mechanical engineering, genetic engineering, space engineering, and electric-electronic engineering. While the names of chemical engineering and space engineering were not mentioned by the experiment group during the pre-interview, they were mentioned during the final interviews. Since chemical engineering was elaborated in two activities and space engineering was elaborated in one activity, they can be stated in the final interviews by students. When asked which information and skills of engineers used in the activities, 3 students in the experimental group emphasized the knowledge on engineering field, precision in measurement, building prototypes, modeling and simulation, quality control, design execution, prediction, problem analyzing, planning, knowledge on engineering branches, data collecting, recording data, teamwork, measurement, describing and analyzing directions, reporting, applying mathematical formulas and setting up mathematics-computer connections.

In the part related to the scientific process skills it is seen that the experimental group students mentioned observing, recording data, classifying, measuring, and communicating skills from the basic scientific process skills. From the experiment confirmation scientific skills, they emphasized inferring, determining variables, prediction, and from the designing authentic experiment scientific process skills, they emphasized hypothesizing, decision making, and experiment setup. It was observed that during the pre-interviews, the experimental group students dwelled more on basic scientific process skills, whereas during the final interviews they mentioned high-level scientific process skills like experiment confirmation and designing authentic experiments as well. About the experiment confirmation process skills, the E1 stressed on the variable setting scientific process skill with the following statement: "We determine our dependent and independent variables."

When the students were asked about the scientific process skills they used during the study, it is seen that they mention observing, recording data, classifying, measuring, communicating, and making number-space connections from the basic scientific process skills. It was determined that they mentioned inferring, determining the variables, prediction, and operational definition from the experiment confirmation process skills, and they stressed hypothesizing, decision-making, using data and modeling, changing and controlling variables, experiment setup from the designing authentic experiment scientific process skills. While talking about the skills of using data and modeling from the designing authentic experiment scientific process skills, the E3 made the following statement: "Based on the research we have, we have built a model."

During the final interviews, when the experimental group students were asked about which details they paid attention to while using their scientific process skills, some students stated that they paid attention to making correct measurements, choosing the right measurement instrument, recording data by using tables and diagrams, using variables while hypothesizing, recording data and details. Two of the students who were asked what level of scientific process skills they used stated that they were above the medium and one of them used a good level of SPS.(during the pre-interview all of the three students told that they used their SPS at a medium level).

When the students are asked about what they think about the contribution of these activities on the development of their scientific process skills and their knowledge and skills related to engineering, they stated that they contributed to the development of their knowledge and skills related to engineering, technology, design, mathematics, and science. When they are asked about the role of the teachers within the process, they mentioned the topics like guidance, developing creativity, warning, teaching engineering skills, ensuring them to solve life problems, showing, observing and preparing them for the next class.

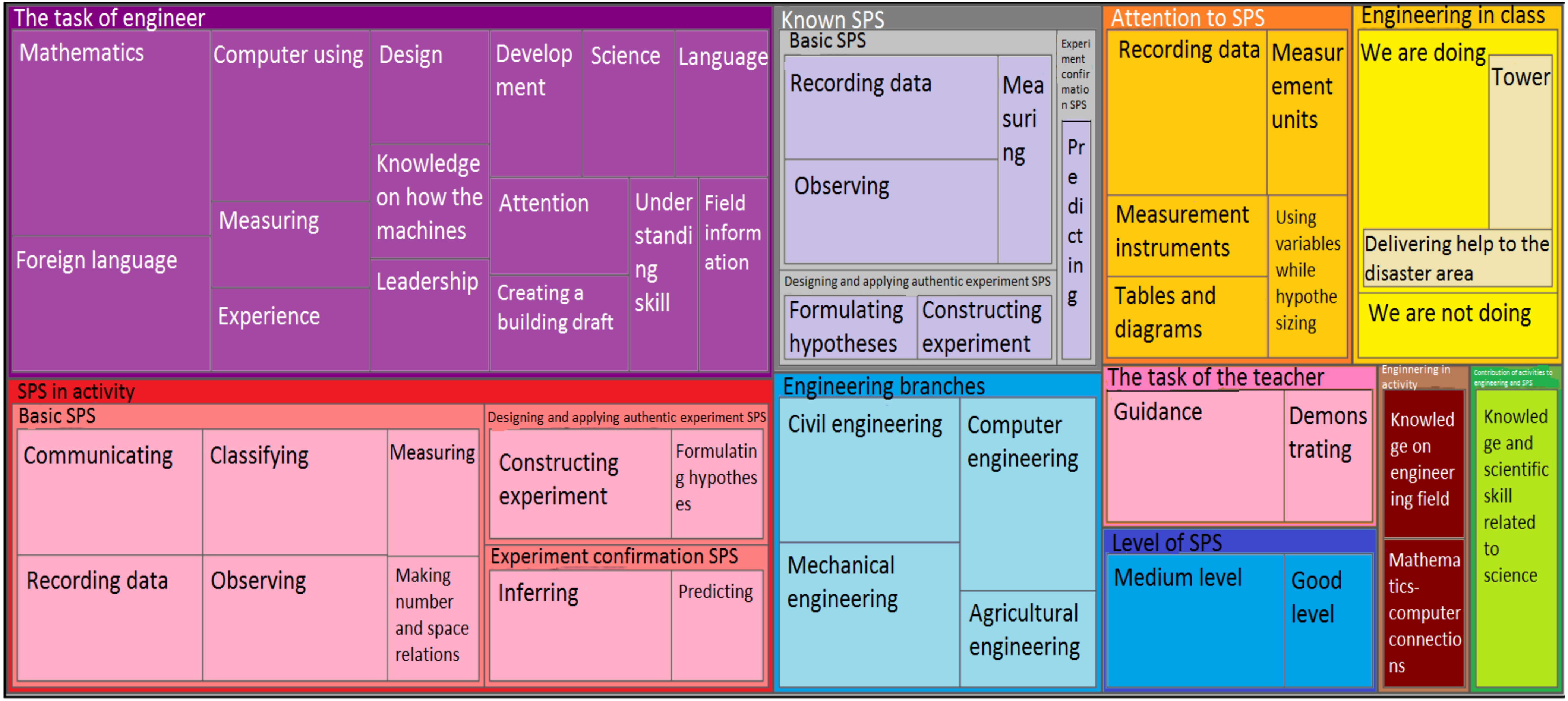

Diagram 6. The hierarchical diagram obtained from the coding of the final interviews conducted with the control group

Diagram 6 shows the hierarchical diagram obtained by coding the control group's final interviews. In the diagram when the 3 students' thoughts from control group regarding the tasks and the skills an engineer has to have been examined, it is seen that they mentioned mathematics, foreign language, computer using, measuring, experience, design, knowledge on how the machines work, leadership, development, science, language, attention, creating a building draft, understanding skill, and field information. For example, the fact that the engineer is required to make designs was stated by the C3 as following "The engineer's task is to make designs." The engineering branches which the control group students emphasized during their final interviews are civil engineering, computer engineering, mechanical engineering, and agricultural engineering. When they are asked about which knowledge and skills used by engineers were applied in those activities, they mentioned knowledge on the engineering field and setting up mathematics-computer connections. During the study, although the control group students didn't use the knowledge and the skills used by engineers in their activities too much, they might have thought that they used knowledge related to this field by nature of some science activities.

In the part related to the scientific process skills it is seen that 3 students from the control group mention observing, recording data, and measuring skills. From the experiment confirmation scientific skills, they emphasized predicting and from the designing authentic experiment scientific process skills, they stated hypothesizing and experiment setup. Regarding the designing and applying authentic experiment scientific process skill, the C2 indicates the experiment setup scientific process skill by stating that: "Firstly we determine a problem for the experiment. Then, we do research about that problem. We put the most appropriate research into practice".

When they are asked about the scientific process skills they used during the study process, it is determined that they mention observing, recording data, classifying, measuring, communicating, and number-space connection setup from the basic scientific process skills. From the experiment confirmation scientific process skills, they emphasized inferring and predicting, and lastly, for the designing authentic experiment scientific process skills, they emphasized hypothesizing and experiment setup.

In their final interviews when the control group students were asked about the details which they paid attention to while they were using their scientific process skills, they stated that they paid attention to recording data by using tables and diagrams, using variables while hypothesizing, recording data, measurement units, and measurement instruments. Two of the students who were asked about at what level they used the scientific process skills stated that they used their SPS at a medium level while one of them stated they used them at a good level.

When the students were asked about their opinion on these activities' contribution to their scientific process skills and their knowledge and skills related to engineering, they said that the activities contributed to the improvement of their scientific skills. Since they didn't do any activities related to engineering, they didn't mention this subject. When the role of the teachers within the process was asked, they stated topics like guidance and demonstration.

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4. RESULTS, DISCUSSION AND RECOMMENDATIONS

When the effect size of the study was calculated considering the scores received from the CBSCT by using the pretest and posttest means, the result obtained was high effect size. This situation indicates that the instruction design based on the STEM approach improved students' scientific creativity.

When the studies in the literature are examined, it is possible to come across the studies revealing that the STEM practices contribute to the improvement of students' problem-solving abilities (Kim and Choi, 2012), creative thinking (Ihrig, Lane, Mahatmya and Assouline, 2018) and 21st-century skills (Abdurrahman, Ariyani, Maulina ve Nurulsari, 2019; Bulut, 2019; Özçelik and Akgündüz, 2018). These studies focused on concepts like creative problem solving, creative thinking, and 21st-century skills which are closely related to scientific creativity. We didn't come across studies conducted with gifted students which directly focus on scientific creativity. In the literature, studies are indicating that STEM activities improve creativity (Kwon, et al., 2012 and Kim, et al.) and the scientific creativity (Ceylan, 2014; Hacıoğlu, 2017) of the students with a normal level of abilities. The studies in the literature demonstrate that creativity in general or scientific creativity can be improved by STEM activities. In STEM studies, students' need to develop products using an interdisciplinary approach, and to use their creativity in developing this product can lead to creativity development in these studies. Considering that scientific creativity is defined as developing original and useful ideas and/or products in the field of science (Sak & Ayas, 2013) and considering that scientific knowledge and skills are required for scientific creativity (Hu & Adey, 2002), it can be assumed that STEM practices conducted both in the current study and in the literature have contributed to the development of scientific creativity by providing students with scientific knowledge. That explains why a context-based scale is used in literature, rather than other scales in scientific creativity. The scale in question is intended to assess creativity concerning each context discussed in this study in the framework of instructional design. Therefore, the quality of an appropriate measurement process was assured.

At the end of the study, findings obtained by the observing data and by the interviews held with 3 students from each group demonstrated that the experimental group students used the scientific process skills more. As a result of the research, the experimental group students stated that they felt more qualified in using the scientific process skills. The observation findings also indicated that the experimental group students' improvement in the scientific process skills is much more than the control group students. Among the basic SPSs, the experiment confirmation SPSs, and designing authentic experiment SPSs, especially the basic SPSs were the most used skills by both groups. One of the limitations of this analysis is that basic SPSs were developed more than the others with STEM activities. Although this study also includes activities involving high-level SPSs, their number is lower than that of basic SPSs. In the STEM practices to be developed from now on, it could be recommended that studies can be performed to improve higher-level SPSs and thereby build higher-level competencies.In the literature, it has been determined that STEM activities contribute positively to the development of scientific process skills of gifted students (Barış and Ecevit, 2019; Cotabish, et al., 2013; Robinson, et al., 2014; Öztürk, Bozkurt-Aslan, and Tan, 2019; Sullivan, 2008) and students with normal ability level (Bozkurt, 2014), Özdoğru, 2013), (Strong, 2013 and Yaman, et al. 2014). Besides, in the study of Choi and Hong (2013) with students with normal ability level, it was stated that there was no significant change in students' scientific process skills.The outcome of this study coincides with the outcomes of the other studies except for Choi and Hong's (2013) study. Various findings in the literature about the influence of STEM practices on the skills of the scientific process show that this issue should be supported by other researchers. At this point, analyses can be made to see what kind of STEM activities improve students' scientific process skills. In this study, almost in every activity, there were activities which aimed to improve the students' scientific process skills. When the teachers' observations were analyzed, it was seen that the students used their scientific process skills in all 7 activities. But it is possible to say that especially the scientific process skills directed at designing and applying authentic experiments become prominent in the activities related to physics. Generally, in all activities, the basic scientific process skills were used intensively and students' improvement in these skills was ensured.

The general outcomes of the research indicated that the instruction design with the STEM approach improved students' engineering skills. In the literature when the studies carried out with gifted studies were analyzed, we are encountered with the studies about the effects of the STEM practices in students' engineering skills conducted by Özçelik and Akgündüz (2018) and Öztürk, Bozkurt-Aslan ve Tan (2019). Dieker, Grillo and Ramlakhan (2012) demonstrated that the gifted secondary school students who had education at a STEM summer camp based on virtual and simulated environments had information about STEM and STEM careers. Dailey, Cotabish and Jackson (2018) in their study based on literature announce that the classroom activities focusing on STEM curriculum and authentic learning experiences, special schools, after school and summer programs, competitions and informal learning opportunities have to be promoted. When the studies conducted with normal students are analyzed in the literature, the study carried out by Ercan (2014) concluded that the STEM activities increased the students' information level on engineering and their consciousness about engineering careers. The outcomes of the studies could be considered to be compatible. Engineering skills are more common in the activities where physics is used from science. This research also includes activities that focus on engineering fields related to chemistry and biology such as chemical engineering, genetic engineering.The general limitation at this stage is the need for engineering tools and equipment for implementation in an area such as Genetic Engineering. This constraint was resolved with support from the university in the present research. To eliminate these restrictions, however, it may be recommended that SACs should be equipped with technological equipment. In STEM-related practices, design tasks that combine not only physics but also chemistry and biology may be suggested.

An instruction design was developed in compliance with the 5E model in this study and applied to gifted students. 21 students performed the activities. At SACs in previous years, students performed tasks in settings with fewer students (such as 6-8 people). The need to work with more crowded groups of students has arisen with the increase in the number of students at SACs in recent years. One of the key issues that teachers claim, though, is that the lessons carried out in crowded groups of gifted students who have specific learning needs are inefficient.As the 21st-century skills of students such as communication and collaboration were expected to be developed throughout the current study of STEM activities, a setting was established in which all students could participate, and tasks were carried out together. In this research, we worked with a total of 21 participants that may be deemed crowded in terms of special education, and since the interdisciplinary approach is utilized, students were able to work together in small groups (5 persons each) throughout the tasks, and the finished products were presented to the whole group. STEM activities formulated within the scope of this study may be used in this sense, particularly where working with crowded groups is required.

When the outcomes of the study related to scientific creativity, scientific process skills, and engineering skill are evaluated together, it can be said that an instruction design in which the STEM approach is used contributes to the improvement of students' scientific creativity, scientific process skills, and engineering skills. This situation indicates that such an instruction design can be used to improve the mentioned skills of students. Therefore, in terms of number and quality, it can be recommended to enhance STEM practices in SAC activity books. While concentrating on STEM practices in the literature studies, the emphasis was on improving either one or two of the skills of scientific creativity, scientific process, or engineering-related knowledge and skills. Unlike other studies, the emphasis of this research was on developing all three skills. Thus, when the activity plans were developed and the teaching practice was carried out, these skills were brought into the center. As stated earlier, 21st-century skills development in the STEM approach is critical.For the gifted students who are supposed to have a place in the country 's future, the development of creativity and scientific creativity, which are among those skills, has specific significance. The need for scientific knowledge and skills for scientific creativity has led the skills of the scientific process to be the focus in the teaching design created. Engineering knowledge and skills are also brought into the core of the STEM approach since students should think like engineers when addressing the problems they face in daily life.Thus, enrichment studies have been given more efficiently, which are essential for SACs. This condition produces both a work limitation and an enrichment. The desire to develop more than one skill in students is causing quite an intense teaching process. The researchers need to concentrate on and manage multiple variables. In this study, by the participation of both researchers and observers in the environment during the process, it was attempted to overcome this difficulty. However, it could be challenging to carry out such research in situations where one person tries to do the task. Researchers who will be developing a similar instructional design can be recommended to consider this situation.

5. REFERENCES

Abdurrahman, A., Ariyani, F., Maulina, H. ve Nurulsari, N. (2019). Design and validation of inquiry-based STEM learning strategy as a powerful alternative solution to facilitate gift students facing 21st century challenging*. Journal for the Education of Gifted Young Scientists,* 7(1), 33-56.

Akkoyunlu, B., Altun, A. ve Yılmaz-Soylu, M. (2008). *Öğretim tasarımı.* Ankara: Maya Akademi.

Almarode, J. T., Subotnik, R. F., Crowe, E., Tai, R. H., Lee, G. M. and Nowlin, F. (2014). Specialized high schools and talent search programs: Incubators for adolescents with high ability in stem disciplines. *Journal of Advanced Academics, 25*(3), 307 –331.

Ataman, A. (2004). Üstün zekâlı ve üstün özel yetenekli çocuklar. M. Şirin., A. Kulaksızoğlu., ve A. Bilgili (Ed.), *Türkiye üstün yetenekli çocuklar kongresi seçilmiş makaleler kitabı* içinde (s. 155-168). İstanbul: Çocuk Vakfı Yayınları.

Ayverdi, L. (2018). *Özel yetenekli öğrencilerin fen eğitiminde teknoloji, mühendislik, matematiğin kullanımı: FeTeMM yaklaşımı* (Yayımlanmamış doktora tezi), Balıkesir Üniversitesi, Balıkesir.

Barış, N. ve Ecevit, T. (2019). Özel yetenekli öğrencilerin eğitiminde STEM uygulamaları. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi,* 13(1), 217-233.

Basham, J. D. and Marino, T. M. (2013). Understanding STEM education and supporting students through universal design for learning. *Teaching Exceptional Children,* 45(4), 8-15.

Bildiren, A. (2013). *Üstün yetenekli çocuklar aileler ve öğretmenler için bir kılavuz* (2. Baskı). İstanbul: Doğan Kitap.

Bodur, N. C. (2019). *Özel yetenekli 5.sınıf öğrencileri için öğrenci seçimine dayalı bir modül serisi geliştirme çalışması: bilim ve mühendislik uygulamaları temelli etkinlik atölyeleri* (Yayımlanmamış yüksek lisans tezi), Uşak Üniversitesi, Uşak.

Bozkurt, E. (2014). *Mühendislik tasarım temelli fen eğitiminin fen bilgisi öğretmen adaylarının karar verme becerisi, bilimsel süreç becerileri ve sürece yönelik algılarına etkisi* (Yayımlanmamış doktora tezi), Gazi Üniversitesi, Ankara.

Bulut, M. (2019). *Bilim ve Sanat Merkezlerinde STEM uygulaması ve öğretmenlerin stem uygulaması hakkındaki görüşlerinin incelenmesi* (Yayımlanmamış yüksek lisans tezi), Necmettin Erbakan Üniversitesi, Konya.

Burt, S. M. (2014). *Mathematically precocious and female: self-efficacy and stem course choices among high achieving middle grade students* (Ph.D Thesis). Trevecca Nazarene University School of Education, Nashville.

Büyüköztürk, Ş., Kılıç Çakmak, E., Akgün, Ö. E., Karadeniz, Ş. ve Demirel, F. (2010). *Bilimsel araştırma yöntemleri*. Ankara: Pegem A Akademi.

Bybee, R., W. (2010). What is STEM education?, *Science,* 329 (5995), 996-996.

Ceylan, S. (2014). *Ortaokul fen bilimleri dersindeki asitler ve bazlar konusunda fen, teknoloji, mühendislik ve matematik (FeTeMM) yaklaşımı ile öğretim tasarımı hazırlanmasına yönelik bir çalışma.* (Yayımlanmamış yüksek lisans tezi), Uludağ Üniversitesi, Bursa.

Choi, Y. and Hong, S.H., (2013). The development and application effects of steam program about 'world of small organisms' unit in elementary science. *Elementary Science Education,* 32(3), 361-377.

Cohen, B. (2008*). Explaining psychological statistics (3rd ed.).* New York: John Wiley & Sons.

Creswell, J. W. and Plano Clark, V. L. (2014). Karma yöntem desen seçimi (A. Delice, Çev.). *Karma yöntem araştırmaları tasarımı ve yürütülmesi* içinde (s. 61-116). Ankara: Anı Yayıncılık.

Cotabish, A., Robinson, A., Dailey, D. and Hughes, G. (2013). The effects of a STEM intervention on elementary students' science knowledge and skills. *School Science and Mathematics,* 113 (5), 215-226.

Dailey, D., Cotabish, A. and Jackson, N. (2018). Increasing early opportunities in engineering for advanced learners in elementary classrooms: a review of recent literature. *Journal for the Education of the Gifted*, 41(1), 93 –105.

Dieker, L., Grillo, K. and Ramlakhan, N. (2012). The use of virtual and simulated teaching and learning environments: Inviting gifted students into science, technology, engineering, and mathematics careers (STEM) through summer partnerships. *Gifted Education International,* 28(1), 96–106.

Ercan, S. (2014*). Fen eğitiminde mühendislik uygulamalarinin kullanimi: tasarim temelli fen eğitimi (*Yayımlanmamış doktora tezi), Marmara Üniversitesi, İstanbul.

Gür, Ç. (2017). *Eğitimsel ve sosyal-duygusal bakış açısıyla üstün yetenekli çocuklar.* Ankara: Anı Yayıncılık.

Hacıoğlu, Y. (2017). *Fen, teknoloji, mühendislik ve matematik (STEM) eğitimi temelli etkinliklerin fen bilgisi öğretmen adaylarının eleştirel ve yaratıcı düşünme becerilerine etkisi* (Yayımlanmamış doktora tezi), Gazi Üniversitesi, Ankara.

Hu W. and Adey P. (2002). A scientific creativity test for secondary school students. *International Journal of Science Education*, 24(4), 389-403.

Ihrig, L. M., Lane, E. L., Mahatmya, D. and Assouline, S. G. (2018). STEM excellence and leadership program: increasing the level of STEM challenge and engagement for high-achieving students in economically disadvantaged rural communities. *Journal for the Education of the Gifted, 41*(1) 24–42.

Katehi L., Pearson, G., and Feder, M. (2009). *Engineering in K-12 education: understanding the status and improving the prospects* (*Report from the Committee on K-12 Education for the National Academie).* Washington DC: The National Academies Press.

Kim, G.S. and Choi, S.Y., (2012). The effect of creative problem solving ability and scientific attitude through the science based STEAM program in the elementary gifted students. *Elementary Science Education*, 31(2), 216-226.

Kim, M., Cross, J. and Cross, T. (2017). Program development for disadvantaged high-ability students*. Gifted Child Today,* 20 (2), 87-95.

Kwon, S.B., Nam, D.S. and Lee, T.W., (2012). The effects of STEAM-based integrated subject study on elementary school students' creative personality. *The Korea Society of Computer and Information,* 17(2), 79-86.

Mann, E. L., Mann, R. L., Strutz, M. L., Duncan, D. and Yoon, S. Y. (2011). Integrating engineering ınto k-6 curriculum: developing talent in the stem disciplines. *Journal of Advanced Academics*. 22(4), 639 –658.

Marland, S. P. (1972). *Education of the gifted and talented* (2 Vols.). Report to congress of the United States Commissioner of Education, Washington, DC: US Government Printing Office.

Meador, K. S. (2003). Thinking creatively about science suggestions for primary teachers. *Gifted Child Today.* 26(1), 25-29.

MEB. (2016a). *Bilim ve Sanat Merkezleri yönergesi.* (2016, 10 Ekim). Erişim adresi: https://orgm.meb.gov.tr/meb_iys_dosyalar/2016_10/07031350_bilsem_yonergesi.pdf

MEB. (2016b). *STEM eğitimi raporu*. Erişim adresi: http://kavak.meb.gov.tr/meb_iys_dosyalar/2016_10/05085558_stem_egitimi_raporu_130_sayfalar.pdf

MEB (2017) *BİLSEM Fen bilimleri dersi çerçeve programı.* (2017, 8 Ekim). Erişim adresi: http://bilsem.meb.gov.tr/login.aspx.
Ocak, M. A. (2015). Öğretim tasarımı modelleri. M. A. Ocak (Ed.), *Öğretim tasarımı kuramlar, modeller ve uygulamalar,* Ankara: Anı Yayıncılık.

Okulu, H. Z. (2019). *STEM eğitimi kapsamında astronomi etkinliklerinin geliştirilmesi ve değerlendirilmesi* (Yayımlanmamış doktora tezi), Muğla Sıtkı Koçman Üniversitesi, Muğla.

Olszewski-Kubilius, P. (2009). Special schools and other options for gifted STEM students. *Roeper Review,* 32(1), 61-70.

Özçelik, A. ve Akgündüz, D. (2018). Üstün/özel yetenekli öğrencilerle yapılan okul dışı STEM eğitiminin değerlendirilmesi. *Trakya Üniversitesi Eğitim Fakültesi Dergisi, 8*(2), 334-351.

Özdoğru, E., (2013). *Fiziksel olaylar öğrenme alanı için lego program tabanlı fen ve teknoloji eğitiminin öğrencilerin akademik başarılarına, bilimsel süreç becerilerine ve fen ve teknoloji dersine yönelik tutumlarına etkisi* (Yayımlanmamış yüksek lisans tezi), Dokuz Eylül Üniversitesi, İzmir.

Öznacar, M.A. ve Bildiren, A. (2012). *Üstün zekalı öğrencilerin eğitimi ve eğitsel bilim etkinlikleri.* Ankara: Anı Yayıncılık.

Öztürk, N., Bozkurt Altan, E. ve Tan, S. (2019). Ortaokul öğrencilerinin "geleceğe hazirlaniyorum: problemlere çözüm ariyorum" projesinin kendilerine katkilarina yönelik değerlendirmelerinin incelenmesi. *Milli Eğitim Dergisi,* 49(225), 153-179.

Robinson, A., Dailey, D., Hughes, G. and Cotabish, A. (2014). The effects of a science focused stem intervention on gifted elementary students' science knowledge and skills. *Journal of Advanced Academics*, 25(3), 189-213.

Sak, U., ve Ayas, B. M. (2013). Creative scientific ability test (C-SAT): A new measure of scientific creativity. *Psychological Test and Assessment Modeling,* 3(55), 315 – 328.

Seren, S. (2019). *Üstün yetenekli öğrencilerle STEM etkinliklerinin tasarlanması ve STEM etkinliklerinde 3 boyutlu teknolojilerin kullanılması* (Yayımlanmamış yüksek lisans tezi). Kocaeli Üniversitesi, Kocaeli.

Strong, M. G. (2013). *Developing elementary math and science process skills throughengineering design instruction*. (MsC Thesis), Hofstra University, Hofstra.

Turiman, P. Omar, J., Daud, A. M. and Osman, K. (2011). Fostering the 21st century skills through scientific literacy and science process skills. *Procedia - Social and Behavioral Sciences,* 59, 110-116.

Üstündağ, T. (2009). *Yaratıcılığa yolculuk* (4. Baskı). Ankara: Pegem A Akademi.

Willis, A. J. (2017). *Women's choice in college stem majors: impact of ability tilt on women students' educational choice* (PhD Thesis). Minnesota State University, Mankato, Minnesota.

Yamak, H., Bulut, N. ve Dündar, S. (2014). 5. sınıf öğrencilerinin bilimsel süreç becerileri ile fene karşı tutumlarına FeTeMM etkinliklerinin etkisi. *Gazi üniversitesi Eğitim Fakültesi Dergisi,* 34(2), 249-265.

Yıldırım, B., ve Selvi, M. (2015). Adaptation of STEM attitude scale to Turkish. *Turkish Studies-International Periodical for the Languages, Literature and History of Turkish or Turkic,* 10(3), 1107-1120.

Young, J. L., Young, J. R. and Ford, D. Y. (2017). Standing in the gaps: examining the effects of early gifted education on black girl achievement in STEM. *Journal of Advanced Academics, 28*(4), 290-312.

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The authors declare that there is no conflict of interest.

6. GENİŞ ÖZET

Fen, Teknoloji, Mühendislik ve Matematik alanlarının birlikte öğretimine dayanan bütünleşik bir öğretim yaklaşımı olan FeTeMM, 1990'lı yıllarda ABD'nde ortaya çıkmıştır. Amacı daha çok ABD'deki teknik eleman ihtiyacını karşılamak olan bu yaklaşım, teknolojik ve mühendislik uygulamaların fen ve matematiğe uygulanması esasına dayanmaktadır ve ABD'den sonra pek çok farklı ülkede de yaygınlaşmıştır. Özel yetenekli öğrenciler anlamında, yurt dışında FeTeMM uygulama örnekleri ile karşılaşmak mümkündür. Ancak, ülkemizde özel yetenekli öğrencilerin eğitiminde kullanılabilecek ülkemize özgü uygulamaların sayısı sınırlıdır. Özel yetenekli öğrenciler, akranlarına göre farklı ilgi alanları ve yeteneklere sahip olduklarından onlara sunulan eğitimin de farklılaştırılmış bir anlayışla sunulması gerekmektedir. Bu bağlamda, özel yetenekli öğrencilerle gerçekleştirilebilecek etkinlik örnekleri ve öğretim tasarımı ihtiyacı ortaya çıkarmaktadır.

Bu çalışmanın amacı, özel yetenekli öğrencilerin eğitiminde kullanılabilecek FeTeMM yaklaşımına uygun olarak geliştirilen bir öğretim tasarımının öğretim sürecine etkilerinin incelenmesidir. Araştırmada karma yöntem araştırma desenlerinden gömülü deneysel desen kullanılmıştır. Çalışma grubunun belirlenmesinde, amaçlı örnekleme yöntemlerinden olan tipik durum örnekleme yöntemi kullanılmıştır. Çalışmada, deney grubunda 9 kız, 12 erkek; kontrol grubunda 8 kız 12 erkek olmak üzere 5-6-7-8. Sınıfta öğrenim gören 41 özel yetenekli öğrenciyle çalışılmıştır. Nitel veri toplama aşamasında, deney ve kontrol grubundan üçer öğrenci ile uygulama öncesi ve sonrasında yarı-yapılandırılmış görüşmeler gerçekleştirilmiştir. Bu öğrencilerin belirlenmesinde maksimum çeşitlilik örnekleme yöntemi kullanılmıştır. Ayrıca süreç boyunca gözlem yapılmıştır.

Deney grubunda, FeTeMM yaklaşımına uygun olarak hazırlanan öğretim tasarımı, kontrol grubunda BİLSEM'lerdeki standart etkinlikler uygulanmıştır. Deney ve kontrol gruplarının denkliği; cinsiyet, sınıf düzeyi, FeTeMM Tutum Ölçeği üzerinden sağlanmıştır. Ölçek, Faber, Unfried, Wiebe, Corn, Townsend ve Collins (2013) tarafından geliştirilmiş, Yıldırım ve Selvi (2015) tarafından Türkçeye uyarlanmıştır. Nicel veriler; Ayverdi (2018) tarafından geliştirilen Bağlam Temelli Bilimsel Yaratıcılık Testi (BTBYT) ile toplanmış ve SPSS 22 Paket Programı kullanılarak analiz edilmiştir. Nitel veriler; gözlem ve görüşme formları ile toplanmış ve Nvivo 11 programı ile analiz edilmiştir. Formların oluşturulmasında, bilimsel süreç becerilerine ilişkin olarak yapılan sınıflamada ele alınan beceriler ve Milli Eğitim Bakanlığı tarafından yayımlanan STEM Eğitimi Raporu (2016b)'ndan faydalanılmıştır. Gözlem ve görüşme formları ile ilgili 3 uzmanın görüşüne başvurulmuş ve uzman önerileri doğrultusunda, formda gerekli düzenlemeler yapılmıştır. Araştırmada gözlemci, hazırlanan gözlem formunu kullanılarak önceden belirlenen kodlama sistemi doğrultusunda yapılandırılmış gözlem gerçekleştirmiştir.

Çalışmada kullanılan öğretim tasarımı, genel öğretim tasarım modeline uygun olarak oluşturulmuştur. Bu model; analiz, tasarım, geliştirme, uygulama ve değerlendirme aşamalarını içermektedir (Ocak, 2015; Akkoyunlu, Altun ve Yılmaz-Soylu, 2008). Bu aşamalara uygun olarak belirlenen bağlamlar (Bilimsel Bilgi, Uzay Araştırmaları, Elektrik, Kimyasal Tepkimeler, Asit ve Bazlar, Genetik Mühendisliği, Ekosistemdeki Bozulmalar) doğrultusunda öğretim tasarımı oluşturulmuş ve deney grubundaki öğrencilerin hep birlikte oldukları bir ortamda uygulanmıştır. Belirlenen bağlamların öğretimi için fen bilimleri öğretim programı ve çerçeve programında yer alan kazanımlar incelenerek bunları zenginleştirmek amacıyla bazı üst düzey kazanımlar eklenmiştir. FeTeMM alanlarından, teknoloji, mühendislik, matematik ve 21. Yüzyıl becerilerine ilişkin kazanımlar, ilgili alan uzmanları ile iş birliği yapılarak ve öğretim programlarındaki kazanımlar incelenerek oluşturulmuştur. Kontrol grubunda ise, kazanımların zenginleştirilmesinden önceki hali için var olan standart fen etkinlikleri kullanılmıştır (Kontrol grubundaki bu etkinliklerin bir kısmı BİLSEM'ler için geliştirilen etkinlik kitabında yer almakta, bir kısmı ise araştırmacılardan biri tarafından etkinlik kitabı geliştirilmeden önceki süreçten beri BİLSEM'de uygulanmaktadır. BİLSEM'lerde öğrencilere yetenekleri doğrultusunda eğitim verilmesi amaçlandığından, etkinlik kitabı geliştirildikten sonraki süreçte de kitap dışında kalan farklı etkinliklere yer verilmektedir).

Deney grubu için 5E modeline uygun olarak hazırlanan öğretim tasarımında, bilimsel yaratıcılığa ilişkin kazanımlar, giriş kısmında dikkat çekme ve ön bilgileri yoklama noktasında kullanılmıştır. Derinleştirme basamağında öğrencilerin ürettikleri ürünlerin bilimsel yaratıcılığa sahip olması için yönlendirmeler yapılmıştır. 5E'nin diğer kısımlarında da kullanılmakla birlikte, özellikle giriş ve derinleştirme basamakları, bilimsel yaratıcılığı kullanmaya ve geliştirmeye yönelik olarak tasarlanmıştır. Bilimsel süreç becerileri, keşfetme basamağında gerçekleştirilen deneysel çalışmalar esnasında kullanılacak şekilde planlanmıştır. FeTeMM'in özellikle mühendislik bir çalışma yapılmasına yönelik kısmı da derinleştirme basamağında kullanılacak şekilde tasarlanmıştır. Değerlendirme ise; içerik, süreç ve ürüne yönelik olarak yapılmıştır. Deney ve kontrol grubunda da 56 saatlik bir uygulama yapılmıştır.

Öğretim tasarımının öğrencilerin bilimsel yaratıcılıkları üzerinde etkili olup olmadığını belirlemek için Tekrarlı Ölçümler İçin İki Faktörlü ANOVA (Two-way ANOVA for Repeated Measures) testi yapılmıştır. Uygulama sonunda, BTBYT puanları açısından deney ve kontrol grupları arasında istatistiksel olarak anlamlı bir fark oluşmuştur. Çalışmanın sonucunda hem gözlem verilerinden elde edilen bulgular hem de her iki gruptan da üçer öğrenci ile gerçekleştirilen görüşmeler, deney grubundaki öğrencilerin bilimsel süreç becerilerini daha fazla kullandıklarını göstermiştir. Araştırma sonucunda, deney grubu öğrencileri kendilerini bilimsel süreç becerilerini kullanma konusunda daha yeterli hissettiklerini belirtmişlerdir. Gözlem bulguları da deney grubundaki öğrencilerin bilimsel süreç becerileri konusundaki ilerlemelerinin kontrol grubuna göre daha fazla olduğunu göstermiştir. Temel BSB, deney doğrulama BSB ve özgün deney tasarlama BSB'nden, özellikle temel BSB'leri her iki grupta da en fazla kullanılan beceriler olmuştur. Sonuçlar doğrultusunda, FeTeMM etkinliklerinin özel yetenekli öğrencilerin eğitiminde daha fazla kullanılması ve BİLSEM etkinlik kitaplarının bu türden etkinlikleri daha çok içerecek şekilde zenginleştirilmesi önerilebilir.