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Abstract

This study aims to examine the effects of engineering design-based science teaching (EDBST) on classroom teacher candidates' decision-making skills, scientific creativity and engineering design-based process skills. The random design of the quantitative approach with a pretest-posttest control group was used in the study. The study group consists of 60 teacher candidates convenient sampling method and studying at the Faculty of Education Department of Classroom Education of a state university in Ankara in the 2017-2018 academic year. The implementations of the study continued in the Science and Technology Laboratory Applications-II course for 14 weeks in accordance with the content integration of STEM. Study data were calculated through dependent and independent groups t-test, one-way repeated measures ANOVA and multivariate variance analysis (MANOVA). When the results of the study were examined, it was seen that the skills of the classroom teacher candidates, where the courses were taught with engineering design-based science teaching, developed positively.

Introduction

Countries can enable the required workforce by providing innovation based on technological developments. Innovation is the process of enhancing science and technology to provide economic and social benefits. Innovative thinking is important in terms of knowledge generation. Innovative thinking has been discussed since the 2000s, particularly in the USA which significantly, affects the world education system. STEM derived as an educational term in 2001 by Judith A. Ramaley, the director of the National Science Foundation, has become widespread since this date and the engineering process has started to be included in the inquiry-based science education (Schwartz et al., 2007). STEM consists of the abbreviations of the first letters of the words "Science, Technology, Engineering and Mathematics. In recent years, many countries have started to include STEM education, where the engineering process is effective in their curricula to comply with global world standards. The engineering process in education provides meaningful learning by establishing a connection between STEM disciplines with knowledge learned and knowledge experienced in the real world (Çorlu & Çalli, 2017, p.11-14). Real-world problems are addressed in engineering design-based learning processes, which have become widespread in the world. In K-12 education, students are asked to produce solutions to the problems encountered in the real world by benefitting from the engineering understanding (Brophy et al., 2008). In the engineering process in education, disciplines such as science, technology and mathematics are used to produce solutions for problems (Çorlu & Çallı, 2017, p.11-14). The content of the disciplines, such as science and mathematics, which are among the basic sciences, is combined with the content of technology and engineering disciplines. As a result, the concept of "integrated STEM" emerges. In integrated STEM, the important point is not to consider the knowledge and skills in the fields of science, mathematics, technology and engineering separately; on the contrary, to create 'knowledge-based ideas' that connect these four fields to each other (National Academy of Engineering [NAE] and National Research Council [NRC], 2009). In this context, disciplines need to be integrated into the concept of STEM (Aslan-Tutak et al., 2017).

In the literature, although there are various approaches where STEM disciplines are integrated into the education process, three approaches are frequently mentioned. These are multidisciplinary, interdisciplinary and transdisciplinary approaches (Hacıoğlu, 2017). In the multidisciplinary approach, other disciplines are included in an organized way in line with a theme. The information belonging to each discipline is combined around a common theme determined by learning separately (Drake & Burns, 2004). In the interdisciplinary approach, information related to the subject is learned from two or more disciplines, and the barriers of these disciplines are overcome and integrated to gain depth in line with the common objective (Vasquez et al., 2013). In the transdisciplinary approach, a process in which researchers from different disciplines are active to obtain information while investigating a common problem is maintained (Tress et al., 2007). Similarly, the transdisciplinary approach is based on the integration of disciplines on real-world problems (Vasquez et al., 2013). Furthermore, STEM education can be integrated into courses based on content and context. In content integration, multiple STEM content areas are combined in one curriculum with an aim to accomplish big ideas. In context integration, STEM disciplines are used when solving a context-related problem (Moore et al., 2014).

Today, individuals need to have life skills appropriate for the digital age (Resnick, 2002). Developed countries replan their educational processes in order not to fall behind the fast-growing scientific and technological developments. In this process, it is highly important to update curricula (Kaptan & Kuşakçı, 2002; Karahan et al., 2015). In Turkey, there have also been radical changes in science education in the last 30 years (Batı, 2014). In 2013, certain changes were made in the science curriculum and the 4+4+4 education system was put into effect. The objective of this program is to raise well-educated science, literate individuals. Knowledge, Skill, Perception and Science Technology Society Environment (STSE) learning and sub-learning domains were added to the 2013 science curriculum. In the STSE learning domain, there are sub-learning domains such as socio-scientific subjects, sustainable development, social contribution of science, science-career consciousness, nature of science and science and technology relationship (Ministry of National Education [MoNE], 2013). As well as scientific process skills and life skills, engineering design skills were added to the updated science curriculum in 2018. In this way, learners will be ensured to think innovatively, solve problems by integrating STEM disciplines, create products and add value to them (MoNE, 2018).

Thanks to the updated science curriculum, students can gain life skills (such as decision-making, creative thinking, analytical thinking, entrepreneurship, team skill and communication problem-solving) and use them correctly. They are expected to find alternative solutions to the problems they encounter in daily life, be creative while doing this and decide on the most appropriate solution among the available solutions. When the studies conducted on STEM education in our country are examined, it is seen that these are mostly the studies carried out with classroom teacher candidates studying at the department of science teaching or secondary school students (Bozkurt, 2014; Ercan, 2014; Altan et al., 2016; Yıldırım, 2016). In the international literature, it is emphasized that STEM activities need to be included in the K-12 education system and the importance of the use of design-based education especially at primary school level is mentioned (Kolodner et al., 2003; Rogers & Postmore, 2004; Wendell & Rogers, 2013; Adams, 2015; Brown et al., 2016). It is observed that the studies conducted related to design-based practices at the primary school level are insufficient in our country. The lack of long-term studies aimed at practice significantly attracts attention (Acar, 2018; Genek, 2018; Altaş, 2018; Koçak, 2019; Yavuz, 2019). The aim of this study is to investigate the effect of engineering design-based science teaching on decision-making skills, scientific creativities and engineering design-based process skills of classroom teacher candidates. Within the scope of this research, the engineering design-based science teaching (EDBST) was performed with the STEM activities prepared in accordance with content integration.

Engineering design-based science teaching is a teaching approach that uses engineering design and scientific research processes together to enable students to acquire targeted behaviors, to produce alternative solutions to daily life problems, to decide on the most appropriate solution, and to integrate all STEM disciplines (Wendell, 2008). Engineering design-based science teaching should not be understood as transforming science courses into engineering courses. What is important here is the integration of these two areas (Gencer, 2017). The designs made should be used as a tool for generating solutions against scientific knowledge and real life problems (Fortus, et al., (2004). In other words, engineering design-based science teaching is a common combination of scientific research and engineering design. In an engineering design-based science education, designs include problems students may encounter in daily life. It is important for students to choose the most appropriate solution among the solutions for these problems in terms of understanding that a problem has more than one solution. It also contributes to the development of higher-order thinking skills of students such as creativity, critical thinking and problem solving (Wendell, 2008). Engineering design based science teaching; It aims to integrate the fields of science, technology, engineering and mathematics, to enable students to work by bringing together different disciplines like an engineer, and to come up with a product by finding creative solutions to problems (Bybee, 2010).

In this study, engineering design process steps were used in the experimental group. The process in question starts with the determination of the problem, the possible solutions are searched and the most suitable solution is selected according to the characteristics of the problem, a prototype for the solution is made and tested, if it does not work, it is revised or rebuilt. While the course was taught with the classroom teacher candidates in the control group in line with the 5E learning model, the EDBST embedded in the 5E learning model was applied to the classroom teacher candidates in the experimental group. This study is important in terms of putting forward the activity examples suitable for science and engineering learning outcomes in the science curriculum and guiding classroom teacher candidates who will be the implementers of the curriculum regarding the engineering design-based process.

The main problem statement of this research is "what is the effect of engineering design-based science teaching on decision-making, scientific creativity and engineering design-based process skills of classroom teacher candidates?"

The problems and sub-problems proposed in compliance with the purpose of the research are listed below:

1. Does the engineering design-based science teaching (EDBST) process affect the decision-making skills of classroom teacher candidates?

 1.1) Is there a significant difference between the pre-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
 1.2) Is there a significant difference between the post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
 1.3) Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?
 1.4) Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model?

2) Does the engineering design-based science teaching (EDBST) process affect the scientific creativity of classroom teacher candidates?

 2.1) Is there a significant difference between the pre-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
 2.2) Is there a significant difference between the post-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
 2.3) Is there a significant difference between the scientific creativity sub-dimensions posttest mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?
 2.4) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?
 2.5) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the 5E learning model?

3) How do the engineering design-based process skills mean scores of the classroom teacher candidates change at the end of the EDBST embedded in the 5E learning model where six different designs were made?

 3.1) Is there a significant difference between the engineering design-based process skill mean scores of the classroom teacher candidates at the end of EDBST embedded in the 5E learning model where six different designs were made?

Method

Research Model

In this study, a quantitative process approach was followed and the random design with pretest-posttest experimental and control groups, which is one of the semi-experimental designs in which the effect of the independent variable on the dependent variable was examined, was used. The experimental and control groups were randomly assigned from ready groups (Büyüköztürk et al., 2012). While the course was taught with the classroom teacher candidates in the control group according to the 5E learning model, the process of EDBST embedded in the 5E learning model was applied to the classroom teacher candidates in the experimental group. Before and after the process, the decision-making skill test and scientific creativity skill test were applied to the classroom teacher candidates in the experimental and control groups. Furthermore, the teacher candidates were evaluated through the engineering design process form that they filled out every week throughout the study. The information regarding the implementation process of the study is shown in Table 1.

Table 1.Implementation process of the study

Group	Pretest	Procedure	Posttest
Control Group (Classroom Teacher Candidates)	Decision-Making Skill Test Scientific Creativity Test	5E Learning Model	Decision-Making Skill Test Scientific Creativity Test
Experimental Group (Classroom Teacher Candidates)	Decision-Making Skill Test Scientific Creativity Test	5E Learning Model + STEM Education (Engineering Design-Based Science Teaching)	Decision-Making Skill Test Scientific Creativity Test

Population and Sample of the Research

The pilot study of the research was carried out with the teacher candidates studying in the fourth grade in the department of classroom teaching of a state university in Ankara in the 2017-2018 fall semester. Pilot studies, where eight volunteer teacher candidates participated as two males and six females, continued for six weeks.The universe of the main study is made is composed of three branches which of the classroom teaching department of the university where the pilot study is made; the sampling of the study, is composed of two branches determined by an random assignment from the universe. As pretest, Decision-Making Skill Test (DMST) was applied to three classes of the second grades of the department of classroom teaching, and as a result of the analyses performed, it was observed that the decision-making skill mean scores of the classes were close to *each other. The general mean scores of DMST were found as Class A* $\bar{X}$*=17.11; Class B* $\bar{X}$=16.07; Class C $\bar{X}$*=17.9*, respectively. In the random assignment performed within the groups, the class 2-A was determined as the control group and the class 2-B as the experimental group. As in the experimental group, the courses were taught with engineering design-based science teaching in class 2-C. The course contents were arranged in line with the expert feedbacks received from this course and used in other classes. The courses were taught in accordance with the engineering design-based science teaching embedded in the 5E learning model in the class 2-B, which is the experimental group, and according to the 5E model in the class 2-A, which is the control group.

According to the DMST pretest scores of 27 teacher candidates in the experimental group, they were heterogeneously divided into six groups as Group 1 (4 individuals), Group 2 (5), Group 3 (5), Group 4 (4), Group 5 (4) and Group 6 (4). Table 2 shows the distribution of the study sample by gender.

Table 2. Distribution of the sample by gender

	Female	Male
Control Group	27	6
Experimental Group	25	2
Total	52	8

Data Collection Tools

Decision-Making Skill Test

The Decision-Making Skill Test (DMST), which was developed by Ercan and Bozkurt (2014) for the students at the secondary school level, is one of the data collection tools used in the quantitative data collection process of this study. This test was reorganized by Bozkurt (2014) in compliance with the classroom teacher candidates, and validity and reliability studies were conducted. The items in the test consist of the questions that include giving answers by paying attention to the multiple criteria in certain characteristics to be measured.

The mean difficulty of the test, which consists of 11 items that have only one correct answer for each question, is 0.52. Moreover, there are three difficult, three easy, and five medium difficulty questions in the test. The internal consistency coefficient of the test rearranged for the teacher candidates is 0.71. The KR-20 reliability coefficient of the test applied to third-grade teacher candidates was calculated as 0.59 in the study. It can be stated that DMST is moderately reliable since its reliability coefficient is between 0.50 and 0.80 (Salvucci, Walter, Conley, Fink, & Saba, 1997). An example question of a decision-making skill test is given below:

The following information will be needed to solve questions 1, 2 and 3. Serkan's father, Yakup Bey, who is a student at a primary school in Sinop district center, is planning to open stationery. He determined 6 place options for him to open the stationery and listed them as follows.

Yakup Bey, together with his son Serkan, prepared some criteria determining the importance of the options in order to decide on one of the 6 options and transferred them to the table below.

Criteria / Options	Place A	Place B	Place C	Place D	Place E	Place F
Competition Conditions	8	6	8	8	4	7
Proximity to the Center	4	9	7	3	6	6
Finding a School Nearby	6	7	6	5	6	7
Store Rents	6	4	7	6	5	7
Finding a suitable width shop	4	3	4	4	3	6

The score application related to the criteria given in the table was made over 10 points.

1. The high-scoring option for one criterion is the most suitable for opening stationery, the lower-scoring option less suitable. For example, for the shop rents criterion, 10 points indicate that the rent is very suitable, 1 point indicates that the rent is not suitable. First of all, it pays attention to the conditions of competition and then the other criteria. Which location option would be most appropriate for Mr. Yakup, who included it in the evaluation?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

2. Serkan, who thinks that the criteria of renting a shop and having a school nearby are more important than other criteria for their decision, which place option would be most appropriate for Serkan to suggest to his father?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

3. When scores between 1-4 are unsuccessful, scores between 5-7 are acceptable, and scores between 8-10 are considered to be very successful in the scoring performed on the criteria, it is most appropriate for Mr. Yakup and Serkan, considering all the criteria, to choose which place for stationery?

A) Place A B) Place B C) Place C D) Place D E) Place E F) Place F

Scientific Creativity Test

Scientific Creativity Test (SCT) was developed by Hu and Adey (2002) in accordance with the scientific creativity model. In this model, there are three main dimensions; a) process (dreaming, thinking), b) traits (fluency, flexibility, originality), and c) product (incentive product, science, science phenomenon, science problem). SCT, which was adapted into Turkish by Kadayıfçı (2008), was applied to 64 students in the 9th grade. As a result of the factor analysis performed to test the construct validity, it was determined that the factor loads of the items were higher than 0.30 and the reliability coefficient of the test was 0.73. In this study, Cronbach's alpha reliability coefficient of SCT applied to the participants was calculated as 0.89. In the test, there are seven open-ended questions. The first question is the unusual uses; the second one is discovering the problem, the third one is developing the product, the fourth one is determining the scientific imagination, the fifth one is solving the problem, the sixth one is applying science experiments. The seventh one is designing the product.

The first question of the scientific creativity test is given below:

1. Write down the possible scientific uses of a piece of glass

The answers to this question were analyzed according to the three main dimensions of the model. The scoring of the question is as follows: 1 point for each answer given (fluency), +1 point (flexibility) for each different application. For each answer seen in less than 5% people, +2 points (for 5-10%) +1 point (originality) is given.

Weekly Engineering Design Process Form

The classroom teacher candidates were asked to complete the design task assigned to them every week in accordance with the EDBST process. In this design process, the teacher candidates used the Engineering Design Process Form developed by the researchers. In accordance with the engineering design process, teacher candidates primarily produced individual solutions for daily life problems based on the learning outcomes determined regarding the learning area. Afterward, all ideas were placed in the decision-making matrix where the criteria and limitations of the problem were included, and the most suitable solution was chosen by the group. After this phase, the teacher candidates performed the prototype drawing. Then, the product was prepared by using the materials to obtain the product. After the preparation, the product was tested and presented. Throughout the process, a total of 36 (thirty-six) designs were produced in the experimental group as 6 (six) designs from each group. In the evaluation of the engineering design process of each group, the engineering design process evaluation rubric (Challenge Rubric) used in engineering education in NASA (2015) Glenn Research Center (GRC) and adapted into Turkish by Uzel (2019) was used. The engineering design process consisting of 8 (eight) stages according to this rubric was evaluated based on three levels (1: Below the targeted level, 2: At the targeted level, 3: Above the targeted level).

Implementation Process

In the pilot study of this research, eight voluntary fourth-grade classroom, teacher candidates were enabled to produce designs in accordance with the primary school fourth-grade science learning outcomes. Before the pilot study, the participants were informed regarding the STEM education process by the researcher. The implementations were performed in the science laboratory at extracurricular hours determined according to the participants. The researcher and the instructor of the course planned 14-week course plans and design processes that were necessary for the main study by benefiting from this pilot study process and literature. Adjustments were made regarding the course plans and design processes by obtaining the opinions of three experts.

In this study, the teacher candidates who participated in the main study took the “Science and Technology Laboratory Applications-I” Course in the fall semester before the study. In this course, Primary School third grade science gains were carried out in the 5E learning model. Therefore, it is thought that teacher candidates have sufficient knowledge about the 5E learning model. At the beginning of the main study, all of the second-grade students were comprehensively informed about the engineering design process. The need for this approach in the education system and its importance in terms of the future of the country were explained to the participants. The students in the experimental group carried out an innovation activity in order to better understand this process that they would perform. In the innovation activity, the students were asked to revise and develop the equipment found in the school in the next 10 (ten) years. Then, they were enabled to draw a prototype. The 3D (Sketch-Up) drawing program was introduced to benefit from the technology while drawing the prototype.

The main study was carried out in the "Science and Technology Laboratory Applications-II" course with the second-grade classroom teacher candidates studying at a public university in Ankara in the spring semester of the 2017-2018 academic year. The courses were taught in accordance with the 5E learning model in the control group and the engineering design-based process embedded in the 5E learning model in the experimental group. In both groups, the courses were conducted by the same researcher and the same subjects were covered. Differently, the engineering design-based process was applied in the experimental group. At the beginning of the implementation, six heterogeneous groups were created from the teacher candidates in the experimental group. In the deepening phase of the 5E learning model, the groups were given daily life problems related to learning outcomes and asked to find solutions by using the engineering design process. In this context, the teacher candidates completed six different design tasks in 14 weeks. In Figure 1, the pictures of the implementation process of the teacher candidates in the experimental groups and their designs can be seen.

Figure 1: Computer use, design process and drawings

One of the applications in the experimental and control group is the Simple Electrical Circuits in the Lighting and Sound Technologies unit. This subject was studied in the control group according to the 5E model, following the introduction, exploration, explanation, deepening and evaluation stages. In the entrance step, students' prior information was checked, their attention was drawn and their motivation for the lesson was provided. During the exploration phase, students were given simple electrical circuit elements to establish circuits and discover faults in the circuit. In the explanation phase, the concepts were first explained to the students and then explained by the teacher. During the deepening phase, the subject was associated with daily life. In this way, students adapt their knowledge and problem solving approach to new events and problems. In the evaluation phase, the process of realizing the educational activities of the students was evaluated by the teacher in all dimensions.

The subject of Simple Electric Circuits was studied in accordance with the engineering design process embedded in the 5E model in the experimental group. In the experimental group, the lessons were taught as in the control group until the deepening stage. During the deepening phase, the following problems related to Simple Electrical Circuits were given to the students.

- “To design lighting tools that can easily make and manage for a few days to meet the lighting needs of the residents in their homes, if electricity cannot be supplied to houses and workplaces due to a major transformer failure in the city.”
- “To design a low-cost lighting device that can draw water from the well in the evenings when there is no light in the garden in a small residential area where water is drawn from a well to houses with a barrel where there is no city water, that can produce electrical energy while drawing the water from the well and thus illuminate the inside and surrounding of the well.”
- “It will enable us to locate our easily lost vehicles such as keys and remote controls we use in daily life; To design a vehicle with a lighting system mounted on the vehicle, connected to a mobile phone or tablet, to be managed with a coding system.”
- “To design a vehicle to be managed with a coding system, connected with a mobile phone or tablet, with a lighting system mounted on the object that will enable us to locate small items lost in bags.”

The students chose one of the above problems as a group and made their designs using the circuit elements. The students started the process by determining the problem, determined possible solution suggestions and chose the most suitable solution among these solutions according to the characteristics of the problem. Later, they drew a prototype for the solution, turned it into a product and presented the product by testing. If the product does not work, they revised it or made it again. The evaluation phase of 5E was done with the measurement tools related to the subject in both the experimental and the control groups.

Data Analysis

In this study, descriptive and predictive statistical analyses were performed. The decision-making skill and scientific creativity mean scores of the teacher candidates in the experimental and control groups before and after the engineering design-based science teaching were calculated and compared with the independent and dependent groups t-test. During the analyses, Cohen's d effect size was calculated for t-test in case that the difference between the groups or variables was significant. For the effect size, Cohen's d values were defined as small, medium and large, respectively as 0.20 (small), 0.50 (medium) and 0.80 (large) (Cohen, 1988; Rosenthal, & Rosnow, 1991). The pretest and posttest mean scores in the fluency, flexibility and originality dimensions, which were the sub-dimensions of scientific creativity, were compared with one-factor MANOVA. Furthermore, the data obtained from the engineering design process forms of the teacher candidates, in the experimental group were rated according to the engineering design process evaluation rubric and the repeated measures were compared by using ANOVA. In the statistics related to parametric tests, the assumptions of normal distribution of the populations and homogeneity of the population variances need to be ensured (Gravetter, 2013). In this study, these criteria were examined in the statistics performed. It was observed that the groups showed normal distribution in the independent group's t-test and the results of the Levene's test revealed a value of $p>0.05$, the equality of the variances was not broken. When the normality assumptions of the test were examined in the dependent group's t-test, it was assumed that the groups showed normal distribution. It is seen that the distribution is normal, and the assumptions of the sphericity test are fulfilled by testing the assumptions of the repeated measures ANOVA. In the one-way MANOVA analysis, it is seen that one-way extreme values and multivariate normality are ensured and the premises of Levene's test are homogeneous.

Validity and Reliability

In data collection and data analysis processes, validity and reliability studies are very important in the interpretation of the data accurately. In quantitative researches, validity is to measure the characteristics that the test aims to measure by separating from other characteristics. Internal validity is the level of explaining the changes observed in the dependent variable with the independent variable. In a research, it is necessary to pay attention to factors that threaten internal validity such as the selection of study group, maturation of the individuals involved in this group for the study, history of the participants, loss effect of the participants, tools used for data collection, pretest effect and interaction effect of the groups (Büyüköztürk et al., 2012). In addition, the consistency of the data is highly essential. In this study, these factors were considered. The classroom teacher candidates were randomly assigned from three classes. The courses in each class were taught according to the 5E learning model appropriate for the same course contents. The duration necessary for the maturation of the study group was taken into consideration. Data collection tools were applied after ensuring validity and reliability. It was paid attention to that the groups were not in interaction with each other. The instructor of the course attended courses with the researcher in all classes. The 14-week period between the pretest and posttest is sufficient for the participants not to remember the pretest.

Principles for Ensuring Reliability

In quantitative researches, reliability is defined as the measuring degree of what is aimed to be measured by the measurement tool, the correct understanding of the characteristics to be measured and the degree of interpretation (Christensen, JohsNson, & Lisa, 2015). The necessary statistical tests were performed for the "Decision-Making Skill Test" and "Scientific Creativity Test" used in the study and reliability coefficients were obtained. It was decided that these tools were reliable measurement tools for the study group.

Findings and Interpretation

In this study, the effect of the Engineering Design-Based Science Teaching (EDBST) on decision-making skills, scientific creativities and design skills of classroom teacher candidates was examined. The findings related to the problem and sub-problems of the study are as follows:

1. Does the engineering design-based science teaching (EDBST) process affect the decision-making skills of classroom teacher candidates?

The mean scores that the classroom teacher candidates in the experimental and control groups received from the Decision-Making Skill Scale were taken into consideration to determine whether the EDBST process affected the decision-making skills of the teacher candidates.

Teacher candidates receive one (1) for each correct answer and zero (0) for each wrong answer in this 11-item test.

1.1. Is there a significant difference between the pre-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Independent t-tests were provided to compare the pre-teaching decision averages of classroom teacher candidates who were taught with the MTTFÖ embedded in the 5E learning model and the classroom teacher candidates who taught the courses with only the 5E learning model.

Table 3. Pre-process decision-making skill mean scores of the classroom teacher candidates

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	0.5187	0.20	-1.576	0.120
Experimental	27	0.5955	0.16		

p>0.05

When Table 3 is examined, it is seen that the difference between the pretest mean scores is not statistically significant [$t(58) = -1.57$, $p>0.05$]. This result reveals that the students in the experimental and control groups are equal in terms of pre-processing decision-making skills.

1.2. Is there a significant difference between the post-process decision-making skill mean scores of the classroom teacher candidates teachers to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Independent t-tests were provided to compare the post-teaching decision averages of classroom teacher candidates who were taught with the MTTFÖ embedded in the 5E learning model and the classroom teacher candidates who taught the courses with only the 5E learning model.

Table 4. Post-process decision-making skill mean scores of the classroom teacher candidates

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	0.5730	0.19	-3.261	0.002*
Experimental	27	0.7172	0.12		

**p<0.05, **p<0.01*

When Table 4 is examined, it is seen that the difference is in favor of the experimental group statistically [$t(58) = -3.21$, $p<0.05$]. The effect size of the difference between the posttest means scores of the experimental and control group was calculated as *Cohen's d: 0.84.* Since this value is in the range of 0.2<d0.8, it is accepted as a large effect, according to Cohen (1988). According to this result, it can be interpreted the EDBST process increased the decision-making skills of the teacher candidates in the experimental group at a higher level compared to the control group.

1.3. Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?

Dependent t-test, whose assumptions were ensured, was performed to compare the decision-making skill mean scores of the classroom teacher candidates in the experimental group before and after the EDBST embedded in the 5E learning model and the results are given in Table 5.

Table 5. Pre-test and post-test mean scores related to decision-making skills of the experimental group

Decision-Making	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	33	0.5955	0.16	-3.525	0.002*
Posttest	27	0.7172	0.12		

**p<0.05, **p<0.01*

When Table 5 is examined, it is seen that, after the EDBST process, the decision-making skill posttest mean scores of the teacher candidates in the experimental group are higher than their pretest mean scores and the difference between the mean scores is statistically significant [$t(26)= -3.52$, $p<0.05$]. The effect size of the difference between pretest and posttest mean scores was calculated as *Cohen's d: 0.68*. This value is accepted as a moderate effect according to Cohen (1988). According to this result, it can be interpreted that the EDBST process increased the decision-making skills of the teacher candidates in the experimental group at a high level.

1.4. Is there a significant difference between the pre-process and post-process decision-making skill mean scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model?

Dependent t-test, whose assumptions were ensured, was performed to compare the decision-making skill pretest and posttest mean scores of the teacher candidates in the control group to whom the courses were taught with the 5E learning model and the results are given in Table 6.

Table 6. *Decision-making pre-test and post-test mean scores of the control group*

Decision-Making	N	$\bar{X}$	sd	t	p
Pretest	33	0.5187	0.20	-1.943	0.061
Posttest	27	0.5730	0.19		

$p>0.05$

When Table 6 is examined, it is seen that the decision-making pretest and posttest mean scores of the teacher candidates in the control group to whom the courses were taught with the 5E learning model are close to each other and the difference is not statistically significant [$t(32) = -1.94$, $p>0.05$].

2. Does the engineering design-based science teaching (EDBST) process affect the scientific creativity of the classroom teacher candidates?

To determine whether the EDBST embedded in the 5E learning model affected the scientific creativity of the classroom teacher candidates, the scores that the teacher candidates in the experimental and control groups received from the Scientific Creativity Test were statistically compared.

2.1. Is there a significant difference between the pre-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

The scientific creativity means scores of the classroom teacher candidates in the control and experimental groups before the EDBST embedded in the 5E learning model were compared with the independent samples t-test, whose assumptions were ensured, and the results are given in Table 7.

Table 7. *Pre-process scientific creativity mean scores of the classroom teacher candidates*

Scientific Creativity	N	$\bar{X}$	sd	t	p
Control	33	4.86	1.49	1.301	0.182
Experimental	27	5.47	2.09		

$p>0.05$

When Table 7 is examined, it is seen that before the EDBST process, there is no statistically significant difference between the scientific creativity pretest mean scores of the teacher candidates in the experimental group and the scientific creativity pretest mean scores of the control group [$t(58) = 1.30$, $p>0.05$]. According to this result, it can be interpreted that the students in the experimental and control groups are equal in terms of scientific creativity.

2.2. Is there a significant difference between the post-process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

Table 8. Post-process scientific creativity mean scores of the classroom teacher candidates

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Control	33	6.45	2.15	-6.25	0.000*
Experimental	27	11.53	3.75		

**p<0.05, **p<0.01*

After the process MTTF, when looking at Table 8; the experimental group and the average of the final test scores of scientific creativity of teacher candidates recent scientific creativity test of the control group from the average score of higher, it is observed that the difference was statistically significant[$t(39,446) = -6,25$, $p<0.05$]. The effect size of the difference between the posttest mean scores of the experimental and control groups was calculated as *Cohen's d: 1.62* and this value is considered as a large effect according to Cohen (1988). According to this result, it can be interpreted the EDBST process increased the decision-making skills of the classroom teacher candidates in the experimental group at a higher level compared to the control group.

2.3. Is there a significant difference between the scientific creativity dimensions posttest mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model and those to whom the courses were taught with 5E learning model?

The data obtained from Scientific Creativity Test (SCT) were analyzed and evaluated by categories in terms of fluency, flexibility and originality, and general scores were obtained. Accordingly, it was seen that there was a statistically significant difference between the posttest scientific creativity mean scores of the control and experimental groups. In addition, while calculating the mean SCT scores, it was examined whether there was a difference between the mean scores in the fluency, flexibility and originality dimensions and the descriptive statistics belonging to the mean scores are given in Figure 2. The posttest mean scores for the fluency, flexibility and originality sub-dimensions of SCT are shown in Figure 2.

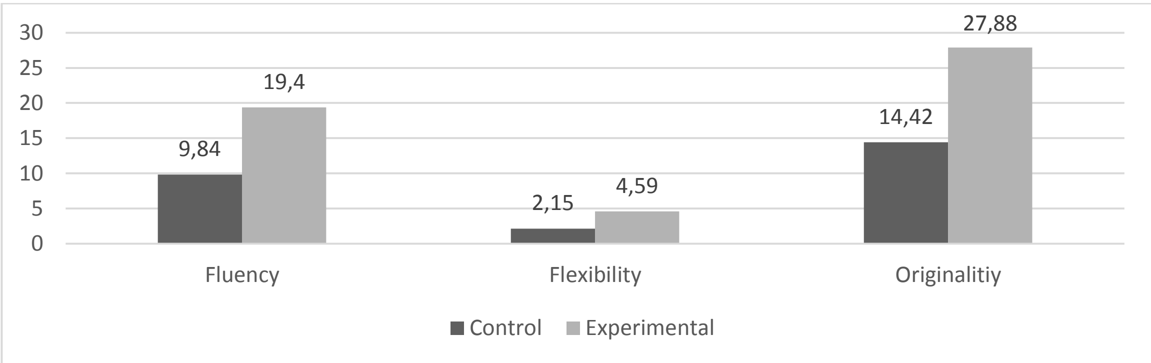

Figure 2: Post-test mean scores regarding the scientific creativity dimensions (fluency, flexibility, originality)

When Figure 2 is examined, it is seen that the SCT posttest scores of the classroom teacher candidates in the experimental and control groups increased in favor of the experimental group in terms of fluency, flexibility and originality. The arithmetic mean, standard deviation, minimum and maximum values related to the SCT posttest of the classroom teacher candidates are given in Table 9.

Table 9. Measures of central tendency scientific creativity dimensions

Scientific Creativity Dimensions	Posttest	*N*	$\bar{X}$	*sd*	*Min.*	*Max.*
Fluency	Control	33	9.84	2.96	5.00	16.00
	Experimental	27	19.40	7.59	9.00	42.00
Flexibility	Control	33	2.15	1.43	0.00	5.00
	Experimental	27	4.59	1.73	2.00	8.00
Originality	Control	33	14.42	7.04	5.00	33.00
	Experimental	27	27.88	12.29	12.00	60.00

When the scores that the teacher candidates received from the fluency sub-dimension of the posttest of SCT were examined in Table 9, it was seen that the scores of the teachers in the control group were between 5.00-16.00 and this distribution was in the range of 9.00-42.00 in the experimental group. While the mean score is 9.84 in the control group, it is 19.40 in the experimental group. While the score in the flexibility sub-dimension of SCT is between 0.00-5.00 in the control group, it is in the range of 2.00-8.00 in the experimental group.

While the mean score is 2.15 in the control group, it is 4.59 in the experimental group. In the originality sub-dimension of SCT, while the control group is between 5-33, the experimental group is in the range of 12.00-60.00. While the mean score is 14.42 in the control group, it is 27.88 in the experimental group. When evaluated in general, it is observed that there is an increase in all dimensions of SCT in favor of the experimental group.

Whether the difference between the mean scores in the dimensions of SCT was significant was evaluated with one-factor MANOVA. When the test assumptions were examined before performing the analysis, two extreme values were excluded from the experimental group to provide one-way and multivariate normality. The mean scores received from the scientific creativity sub-dimensions by the classroom teacher candidates to whom the courses were taught according to the 5E learning model and those to whom the courses were taught with the EDBST embedded in the 5E learning model were compared with one-factor MANOVA and the findings obtained are given in Table 10.

Table 10. Comparison of the sub-dimensions of SCT through MANOVA

Scientific Creativity Dimensions	Posttest	*N*	$\bar{X}$	*sd*	*df*	*t*	*p*	*d*
Fluency	Control	33	9.84	2.96	32	-6.164	0.000*	1.65
	Experimental	27	19.40	7.59	26			
Flexibility	Control	33	2.15	1.43	32	-5.954	0.000*	1.53
	Experimental	27	4.59	1.73	26			
Originality	Control	33	14.42	7.04	32	-5.050	0.000*	1.34
	Experimental	27	27.88	12.29	26			

Considering Table 10, whether there was a difference between the groups in terms of fluency, flexibility, and originality, sub-dimensions of SCT at the end of the EDBST process was evaluated through One-Way Multivariate Analysis of Variance (One-Way MANOVA). When the one-way MANOVA results were examined, a statistically significant difference was observed between the fluency, flexibility and originality sub-dimension mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model compared to the control group to whom the courses were taught with the 5E learning model [*fluency* $F(1\text{-}56) = 47.453$, $p<0.001$], [*flexibility* $F(1\text{-}56) = 32.599$, $p<0.001$], [*originality* $F(1\text{-}56) = 27.068$, $p<0.001$]. The effect sizes of the difference between the mean scores of these sub-dimensions are 0.45; 0.36; 0.32, respectively, and these values ($ή2>0.14$) are interpreted as a high effect. According to this, it can be interpreted that improvement was observed in the teacher candidates in terms of the fluency, flexibility and originality sub-dimensions of the “trait” dimension of scientific creativity.

2.4) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model?

The pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the EDBST embedded in the 5E learning model was calculated and compared with the dependent groups t-test and the results are given in Table 11.

Table 11. Scientific creativity pretest and posttest mean scores of the experimental group trained with EDB

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	27	4.86	2.09	-12.252	0.000*
Posttest	27	11.53	3.75		

**p<0.05, **p<0.01*

When Table 11 is examined, it is seen that after the EDBST process, the scientific creativity posttest mean scores of the classroom teacher candidates in the experimental group are higher than their pretest mean scores and the difference is statistically significant [$t(26)= -12.252$, $p<0.05$]. The effect size of the difference between the pretest and posttest mean scores was calculated as *Cohen’s d: 2.35*. This value is accepted as large effect according to Cohen (1988). According to this result, it can be interpreted that the EDBST process increased the scientific creativity skills of the classroom teacher candidates in the experimental group at a high level.

2.5) Is there a significant difference between the pre-teaching and post-teaching process scientific creativity mean scores of the classroom teacher candidates to whom the courses were taught with the 5E learning model?

Table12. Scientific creativity pre-test and post-test mean scores of the 5e learning model group

Scientific Creativity	*N*	$\bar{X}$	*sd*	*t*	*p*
Pretest	33	5.47	1.49	2.403	0.022*
Posttest	33	6.45	2.14		

$*p<0.05$

The pre-implementation and post-implementation scientific creativity scores of the classroom teacher candidates in the control group to whom the courses were taught with the 5E learning model were calculated and compared with the dependent t-test and the results are given in Table 12. When Table 12 is examined, it is seen that while the scientific creativity pretest mean scores and posttest mean scores of the teacher candidates in the control group are close to each other, the posttest mean scores are higher and the difference is statistically significant [$t(32)= 2.40$, $p<0.05$]. The effect size of the difference between the pretest and posttest mean scores was calculated as *Cohen's d: 0.41*. This value has a moderate effect, according to Cohen (1988). It can be stated that the medium-level increase in the scientific creativity mean scores of the teachers in the control group results from the courses taught with the 5E learning model in accordance with the constructivist education understanding. The teacher candidates participated in the process activities in the step of discovering the 5E learning model and reached explanations by performing various activities. It can be stated that this process increased the creative thinking of the teachers. From this point of view, it can be interpreted that the EDBST process has a high level of effect on the scientific creativity scores of the classroom teacher candidates.

3) How to do the engineering design-based process skill mean scores of the pro-change at the end of the EDBST embedded in the 5E learning model where six different designs were made?

3.1) Is there a significant difference between the engineering design-based process skill mean scores of the classroom teacher candidates at the end of EDBST embedded in the 5E learning model where six different designs were made?

During the EDBST process, the engineering design-based process skill mean scores obtained as a result of six different designs of the teacher candidates in the experimental group were calculated and the results are presented in Table 13. When Table 13 is examined, the change in the mean scores of the classroom teacher candidates in terms of the individual engineering design-based process skill in the EDBST process was determined and presented in Figure 3.

Table13.Engineering design-based process skill mean scores

Group No	*Design 1*	*Design 2*	*Design 3*	*Design 4*	*Design 5*	*Design 6*
1	12	11	10	15	19	20
2	15	16	18	19	20	20
3	12	13	18	16	19	19
4	8	12	13	15	19	20
5	9	14	15	14	21	22
6	11	17	16	19	22	22
Mean Score	11.16	13.86	15	16.33	20	20.5

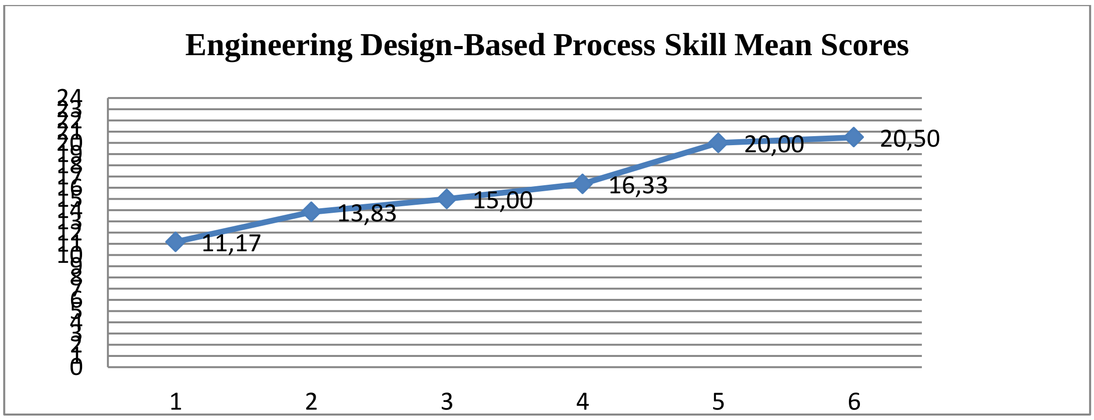

Figure 3: The change between the mean scores related to the engineering design-based process skill

According to Figure 3, the engineering design-based process skill mean scores of the classroom teacher candidates in the experimental group were 11.17 in the first design, it increased to 20.50 in the final design. The teacher candidates to whom the EDBST was applied performed 6 different engineering designs throughout the process. The designs performed by the teachers in the experimental group were evaluated with the engineering design process evaluation rubric and whether there was a difference between the mean scores was investigated with one-way repeated measures ANOVA. The findings obtained as a result of the comparison of the engineering design-based process skill mean scores by using one-way repeated measures ANOVA are presented in Table 14.

Table 14. Results for the comparison of the engineering design-based process skill mean scores

Design	Sum of Squares	sd	Square of Means	F	p	Eta-Square (ή2)
Design	1644.825	2.496	672.155			
Error	342.481	64.902	5.277	127.377	.000*	.830
Total	1987.306	67.398	677.432			

($F_{(2.496;\ 64.902)}$=127.377, p<0.001, ή2=.830)

Looking at Table 14, it was determined that there was an increase in the average scores of experimental classroom teacher candidates for engineering design based process skill from the first design to the last design and that the difference between the average scores was statistically significant (*p<0.05*). The effect size of the difference between the engineering design-based process skill mean scores was calculated as *0.83* and this value was interpreted as a large effect since it was (*ή2>0.14).* At the end of the six designs in which EDBST process was applied, the teacher candidates' engineering design-based process skill mean scores increased significantly. Accordingly, it can be interpreted that the teacher candidates in the experimental group improved their engineering design-based process skills as a result of the implementations. The paired comparisons of the engineering design-based process skill mean scores of the teachers in the experimental group were performed with the Bonferroni test and the results are given in Table 15.

Table 15. Engineering design-based process skill mean scores with the Bonferroni test

Design Pairs	*Mean Difference*	*Sig.*
Designs 1-2	-2.407	0.001*
Designs 1-3	-3.667	0.000*
Designs 1-4	-5.000	0.000*
Designs 1-5	-8.556	0.000*
Designs 1-6	-9.037	0.001*
Designs 2-3	-1.256	0.077
Designs 2-4	-2.593	0.000*
Designs 2-5	-6.148	0.000*
Designs 2-6	-6.630	0.000*
Designs 3-4	-1.333	0.139
Designs 3-5	-4.889	0.000*
Designs 3-6	-5.370	0.000*
Designs 4-5	-3.556	0.000*
Designs 4-6	-4.037	0.000*
Designs 5-6	-0.481	0.000*

**p<0.05, **P<0.01*

When Table 15 is examined, the differences between the engineering design-based process skill mean scores of the teacher candidates in the experimental group during the EDBST process are seen. According to the analysis results, while there is no statistical difference between the mean scores of the design 3 and the designs 2 and 4, there is a statistically significant difference between the design 3 and the designs 5 and 6. All other designs differ from the previous design in terms of both mean score and significance. The increase in the first two designs slowed down in the middle of the continuous and started to rise again. According to this result, it can be interpreted that engineering design-based process skills are gained over time.

Conclusion and Discussion

In this study, the effect of the EDBST process on the decision-making skills and scientific creativity of classroom teacher candidates was investigated. Accordingly, it was concluded that the pretest mean scores of the teacher candidates in the experimental and control groups were close to each other before the EDBST process, and the mean scores increased significantly in favor of the experimental group after the process. When the literature was examined, there were not many studies investigating the effect of design-based teaching processes on decision-making skills. Similarly, to the results of this study, Bozkurt (2014) found that engineering design-based teaching had a positive and large effect on science teachers' decision-making skills. In the study conducted by Ercan (2014) with the primary school 7th-grade students, it was determined that the engineering design-based science teaching applied in the "Force and Motion" unit increased decision-making skills, engineering disciplines and academic achievement levels of the students. In addition, Ercan and Bozkurt (2013) stated that, after the engineering design-based science teaching, positive developments were observed in the decision-making skills of secondary school students. In 2006, NAE and NRC engineering committee prepared the K-12 curriculum that included design-based practices in science teaching in the USA. It is seen that science, mathematics, engineering and technology disciplines are integrated in the K-12 curriculum in order to prioritize the engineering discipline (NAE & NRC, 2009). In the engineering design process, which is increasing in importance, problems are identified first; after the problem is identified, solutions are offered; then the most appropriate solution is decided by making selections in accordance with the criteria and limitations of the problem. Afterward, a prototype is created and the design presented as a solution offered is performed and tested (Koehler et al., 2005). It is highly important to be able to solve problems in the engineering design process and to decide appropriate solutions while doing this (Jonassen, 2011; Kayser 2011). In their study, Dym et al. (2002) compared different solution suggestions in the problem-solving process. It is stated that there are some difficulties when comparing solution suggestions. However, it can be an effective decision-making process. In this study, it is also seen that the decision-making skill mean scores of the classroom teacher candidates increased as a result of DMST in the EDBST process. It can be concluded that the EDBST process affects teachers' decision-making skills considerably and positively. It is thought that teacher candidates can manage an effective decision-making process.

When the results related to the effect of the EDBST process on scientific creativity of classroom teacher candidates were examined, it was observed that the experimental and control groups' scientific creativity pretest mean scores were close to each other before the process and these mean scores increased significantly in favor of the experimental group after the process. When the studies conducted on the subject were examined, Hacıoğlu (2017) determined that the 14-week engineering design-based science practices significantly improved scientific creativity and critical thinking skills of science teacher candidates. Similarly, in their study conducted in Malaysia et al. (2015) conducted an 8-hour project-based STEM workshop with 21 preservice teachers and 21 teachers in service. In the light of the questionnaires, interviews and classroom discussions before and after the practices, it was seen that the STEM activities contributed to the students in terms of generating creative ideas. Moreover, Hacıoğlu (2017) found a significant difference in favor of the experimental group in fluency, flexibility and originality sub-dimensions of SCT. In the applied study on creative thinking in science education, Koray (2014) obtained results in favor of the science teacher candidates in the experimental group in terms of the fluency, flexibility, elaboration and originality sub-dimensions. Kaya (2018) examined the effect of STEM education on science teaching third-grade teacher candidates' creativity and self-regulation skills and specified that these skills developed positively after the implementation. Yıldırım and Türk (2018) continued the 12-week STEM education with 40 teacher candidates in the 2016-2017 academic year and received their opinions regarding STEM education. As a result of the research, the classroom teacher candidates stated that "STEM practices can develop characteristics such as creativity, curiosity, self-confidence and responsibility in students". These studies reveal that there is a connection between engineering design processes and creative thinking. In engineering processes, opinions such as creativity, cooperation, ethics and optimism are also included (NAE & NRC, 2009). When the literature is analyzed, the lack of studies, where STEM activities are applied at the primary school level and the effect of these activities on students' scientific creativity, draws attention. The study of Genek (2018) examined the scientific creativity levels of the first, third and fourth-grade students, who took the STEM course, according to various variables and found that their scientific creativity changed according to their grade levels. Yavuz (2019) conducted science courses in accordance with STEM content with fourth-grade students and concluded that STEM practices were effective in improving students' creativity levels and 21st-century skills. In this study, it was also observed that the teacher candidates had positive developments in their scientific creativity levels during the EDBST process. In addition, positive developments were observed in the teacher candidates in the fluency, flexibility and originality sub-dimensions of the "trait" dimension of creative scientific thinking. Therefore, it can be stated that EDBST practices have a positive and large effect on teacher candidates' scientific creativity levels. In addition, the literature also put forwards that problem solving, producing hypotheses and creating designs in the engineering design process are related to scientific creativity (Lin et al., 2003). Grosul (2010) associates the transfer of creativity to life by combining it with scientific theories with scientific creativity. Similarly, Dağlıoğlu (2010) defines creativity as individuals' thinking of new things, integrating these into their lives and creating innovations. These statements reveal that scientific creativity is used in engineering design processes. In this study, it is thought that classroom teacher candidates can be more successful in managing their scientific processes based on their interpretation that their scientific creativity develops positively, they can transfer innovation to their lives more easily and they will ground creativity on scientific foundations in the engineering design process.

When the results obtained from the data in the engineering design process forms, where the phases of the EDBST process were included, were examined, it was observed that there was a significant difference between in the following weeks and past weeks in terms of the engineering design-based process skills mean scores obtained from six different EDBST practices. Although there was an increase in the mean scores of the design (Effects of Force) in the 3rd week compared to the previous weeks, it was not significant. It is interpreted that this may have resulted from the fact that the content of the learning outcomes in the unit made the design process difficult and the process wasn't understood by the teacher candidates in the course of time. The aim of educating students with engineering design-based processes is to develop products by finding quality solutions to problems by benefiting from an engineering rather than building something and improving their decision-making skills in this process. The success of this process depends on three factors: Students are actually like engineers, teachers should listen to their students and classroom environments need to be adjusted for an effective design process (Hynes et al., 2011). From this perspective, the studies to be conducted about engineering design process are very important. Breiner et al. (2012) stated that STEM education was provided as a discipline integration in the process of thinking like a scientist and an engineer in a study in a university in the USA with STEM education facultyi. Furtermore, in their study, Difrancesca, Lee and McIntyre (2014) expressed that STEM education process was very beneficial for primary school students in terms of finding solutions to the problems they face in daily life, improving their engineering skills and their careers in this field. English and King (2015) examined the design process of the fourth-grade children in the first year of their three-year longitudinal study. The children (problem scope, idea generation, design and production, design evaluation, redesign) performed the design and redesign of a 3D model plane according to the engineering design phases. Particularly, it was seen that the students used STEM discipline knowledge in the last two phases (design evaluation and redesign). It is considered highly important that the engineering design process is a whole; this process is tested and revised when necessary. Similarly, Çorlu and Çallı (2017) explained this process as the use of knowledge in daily life with an interdisciplinary approach according to knowledge-based life problems. In the study conducted by Bozkurt (2014) with the science teacher candidates within the scope of the Science Laboratory Application-I course, it was seen that the science education based on engineering design developed the decision-making and scientific process skills of the participants. It is considered that this education will be very useful for a primary and secondary school science course. Furthermore, Eroğlu and Bektaş (2016) interviewed five science teachers in three different secondary schools and examined the opinions of teachers about STEM-based course activities. Accordingly, it was observed that the teachers associated STEM-based education with the field of physics and established a relationship between science and technology, mathematics and engineering. In another study, semi-structured interviews were conducted with six science teacher candidates regarding the design-based process. As a result, the teachers mentioned about the strengths of the process and stated that the engineering design process contributed to permanent learning (Altan et al., 2016). Furthermore, Altaş (2018) applied the course plans prepared according to STEM education to classroom teacher candidates and investigated their engineering and technological perceptions of using the engineering design process steps. The results of this research also showed that classroom teacher candidates improved in terms of their skills to use engineering design process steps and they would be able to these in their daily lives. The classroom teacher candidates also improved themselves in areas such as managing this process effectively and producing different designs. In their research, Çalışıcı and Sümen (2018) examined the metaphors of 138 teacher candidates about the STEM education approach. The teachers found STEM education very useful by regarding STEM as an ever-evolving and popular educational approach. In their research that they experimentally conducted with the STEM activities, Karışan and Yurdakul (2017) observed positive developments in the attitudes of the experimental group students towards STEM. Seçkin-Kapucu and Karakaya-Özyer (2019) enabled secondary school students to self-evaluate the design process in terms of various variables. The research was carried out in two stages, in the fall and spring term of the 2018-2019 academic year. In the first stage, the scale was developed and in the second stage, the relationship between the scale and other variables was examined. The first stage of the study was conducted with 530 students from 7th and 8th grades, whereas 447 students participated in the second stage. The relationship between perception for problem solving skills and decision-making attitudes, which are considered important in the design process, were examined. As a result of the research, it was determined that the problem solving perception and the cautious selective decision-making style contributed significantly to the self-evaluation of the design process. Similarly, as a result of this study, a statistically significant difference was found between the experimental group in which the design process was applied and the control group in terms of decision-making skills. The design process positively affected pre-service teachers' decision-making skills.

In this study conducted according to the content integration of STEM, in the MTTFÖ process, teacher candidates' decision-making skills, scientific creativity and design-based process skills were positively affected. As a result of this research, the targeted research problems are considered to be answered as expected. Grounding the design with scientific researches in the middle of the plane in Wendell's (2008) design/scientific research-inquiry approach prepared for constructivist science courses was effective in this study. In our country, the science education curriculum based on research-inquiry has been renewed in line with the needs of the age and it has been tried to be integrated with science and engineering skills. With this study, teacher candidates will be able to use the STEM education approach familiarly with the engineering design process and will use STEM education in their teaching processes by understanding the contribution of this process to the 21st-century skills.

Recommendations

In order to overcome some limitations encountered in this study, the information about the process can be provided to the participants at least three weeks before starting the practices for a better understanding of the EDBST process in the long-term practices. In order to benefit from the mathematics discipline in the EDBST process, daily life problems related to mathematics learning outcomes can be identified. In addition, simpler robotic coding, which includes ready coding such as block coding and maker sets, can be used to increase technology awareness among students. Similarly, the EDBST process can be performed with primary school students. In the studies to be conducted, support can be received from primary school students and their teachers. Appropriate environments and materials for STEM education can be provided in schools and universities. The main target in similar practices is to ensure that students are familiar with early engineering education and become productive individuals in their learnings to be performed in accordance with daily life problems. In our country, engineering design-based training to be provided at the primary school level are needed to develop this field.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

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