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INVESTIGATION OF THE IMPACT OF STEM EDUCATION ON THE CREATIVE DESIGN SKILLS OF PROSPECTIVE TEACHERS

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ABSTRACT

This study aims to evaluate the impact of STEM education on the creative design skills of trainee teachers. The sample for the study was made up of third-year prospective teachers studying at the Department of Science Education and Department of Elementary Mathematics Education in the 2020-2021 school year. Embedded mixed design, which is a type of mixed method, was used in the method of the study while the quantitative part of the mixed design was comprised of a one-group pretest-posttest design and the qualitative part was the case study. The implementation was carried out creating lesson plans aimed at STEM activities and process designs, and obtaining products throughout the course of one semester. Looking at the findings of this study, there were significant differences in favour of the posttest scores in all scales. Therefore, the conclusion was reached that the trainee teachers in both groups were observed to have experienced higher self-efficacy in terms of STEM practices, and that, in view of the meaningful rise in the sub-dimensions of the scales, the implementation was found to support the material design process and creativity. Examination of the qualitative data showed the codes support the changes that occurred in the quantitative data. Also, difficulties faced the trainee teachers were examined.

Contribution/ Originality: This research contributes to the existing literature in terms of revealing the ability of science and mathematics prospective teachers to perform design-based STEM applications in the compulsory distance education process. In addition, it is important for prospective teachers to present the difficulties they encountered in the process and the solutions they found to these difficulties in a realistic way in line with their possibilities.

1. INTRODUCTION

STEM education is the process of teaching and learning the disciplines of science, technology, engineering and mathematics (Gonzalez & Kuenzi, 2012). Science, technology, engineering and mathematics education i.e., STEM education, has become more important with the globalisation of economic competition in the 21st century. STEM education focuses on innovation and designing solutions to complex problems by removing the borders between these fields (Kennedy & Odell, 2014). STEM, which is a holistic education that can guide developments in the 21st century, aims to achieve outcomes such as developing creative thinking skills, being innovative and productive, and adopting cooperation (Sirajudin, Suratno, & Pamuti, 2021).

Design based learning, which is one of the common approaches used in STEM education, facilitates the integration of real-life problem-solving processes and the design processes of engineers into the classroom (Felix, 2010 as cited in Bozkurt and Tan (2020)). This approach includes the students in the design process, thereby creating an environment for both the acquisition of the lesson content and the development of design skills. Design based learning also encourages cooperation and guides learners towards teamwork (Kolodner, 2002). Another positive result of this approach is that it improves the engineering knowledge of students by exposing them to the design process (Mehalik, Doppelt, & Schuun, 2008). McCormick, Murphy, and Hennessy (1994) talked about how since the design process could be compared to the job of problem solving, the process included the steps of defining the problem, acquiring information, creating alternative solutions, picking an appropriate solution, designing a prototype and reviewing (Doppelt, 2009). Creative thinking is important int this process, which is also described as the solution generation process (Denson, 2015). Even though there are many definitions of creativity in literature (Kale, 1994; Sungur, 1992; Torrance, 1962) sensitivity in solving the problem, asking questions that go towards solving the problem, creating alternative solutions and different ideas can be considered as common points in the various definitions (Karakuş, 2001). Also, creativity is one of the 21st century learning and innovation skills (Bozkurt & Tan, 2020). In order to investigate creativity in individuals, the level of creative thinking must be researched (Denis-Çeliker & Balım, 2012). While the word creativity may invoke fluidity, flexibility and original thinking (Hu & Adey, 2002; Torrance, 1990) used the phrase scientific creativity to describe creativity in a three-dimensional model. The three dimensions described are process, product and trait, and under these three dimensions there are, in order, imagination and thinking; originality, flexibility and fluency; science problem, science phenomena, science knowledge and technical product. As one can see, the concept of creativity includes certain attributes and these attributes can be considered prerequisites for the emergence of creativity. In light of literature, there are many studies that research creativity in education and the concepts of being design oriented/design based, while there are relatively few studies that include STEM education (Bozkurt, Yamak, Kirikkaya, & Kavak, 2018; Bozkurt & Tan, 2020; Cakır, Yalçın, & Yalçın, 2019; Ciftçi, 2018; Cilengir-Gültekin, 2019; De Vries, 2021; Gülhan & Sahin, 2018; Hacıoğlu, Yamak, & Kavak, 2017; Hathcock, Dickerson, Eckhoff, & Katsioloudis, 2015; Henriksen, 2014; Li et al., 2019; Mayes, Gallant, & Fettes, 2018; Sarıçam, 2019; Siverling, Suazo-Flores, Mathis, & Moore, 2019; Ugras, 2018), and it is thought that this study can contribute to the literature on the subject through the inclusion of these three concepts. It is thought that having more work aimed at STEM, creativity, and design may support individuals' creativity in the design process when dealing with different disciplines, and also have a positive impact on their design skills. Also, creativity and design skills, which are important to every individual, are becoming even more important for future teachers of Science and Mathematics, which are components of STEM. The sub-problems of this study are as follows:

1. Are there any significant differences between the following prospective teacher information for each data collection tool:

a. Pretest-posttest total scores.

b. Pretest-posttest sub-dimension scores.

2. What are the prospective teachers' opinions on before, the process and after the implementation?

2. METHOD

2.1. Research Model

The embedded mixed design, which is a type of mixed method, was used in this study and the quantitative portion of the mixed design was made up of the single group pretest-posttest design in which the experimental process is observed on a single group, whereas the qualitative portion was comprised of a case study in which an event is examined and explained (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz, & Demirel, 2018). The embedded single case design, which is a type of case study, was used in this study. In the embedded case design, there are more than one analysis units within a single design (Yin, 2003). The single case stated in the study is the opinions gleaned from the prospective teachers on the implementation process. The analysis units in the single case are the departments

(Science, Mathematics) the prospective teachers were attending. In the embedded mixed design that includes more than one type of data (quantitative, qualitative), in a study in which there is an experimental design, qualitative data can be applied before, during and after implementation consecutively (Creswell, 2014).

2.2. Sample

The sample of the study is made up of third-year prospective teachers studying at the Faculty of Education Department of Science Education (59 people) and the Department of Elementary Mathematics Education (51 people). While 19.1% of the total participants were male, 80.9% were female (Table 1). Prospective Science teachers were chosen using criterion sampling, which is a type of purposive sampling with the possible criterion identified being the prospective teachers' enrolment in the Material Design in Science Teaching course, whereas the prospective Mathematics teachers were chosen using the convenience sampling method.

Table 1. Sample traits.

Variables		Gender		N	Mean
		Female	Male		
Group	Science	52	7	59	53.64
	Mathematics	37	14	51	46.36
Total		89	21	110	100.00

2.3. Data Collection Tools

In order for the implementation of data collection tools, permission was obtained from the Ethics Committee (XXX University Social Sciences and Humanities Scientific Research and Publishing Ethics Committee approval number 182 dated 23.10.2019) for the use of scales, and permission to apply the data collection tools was also obtained (Faculty of Education permission).

2.3.1. A Teacher Self-Efficacy Scale for STEM Practice

This scale, developed by Yaman, Ozdemir, and Akar-Vural (2018), in which validity and reliability studies were conducted on prospective teachers, is one-dimensional and consists of 18 items. It is a 5-point Likert scale (1:Never, 2:Rarely, 3:Sometimes, 4:Often, 5:Always). The KMO value calculated for the factor analysis was .98, the Bartlett Test results were X^2=208.3, p=.000 (RMSEA= .05, NFI= .99, CFI= 1.00, IFI= 1.00, RFI= .98, GFI= .90 and SRMR= .025). The Cronbach's Alpha internal consistency coefficient was calculated as .97 (Yaman et al., 2018). In this study, the Cronbach Alpha value was calculated as .96.

2.3.2. The "How Creative are you?" Scale

Developed by Whetton and Cameron (2002) and adapted into Turkish by Aksoy (2004), the 39 item 3-point Likert scale (Agree, Undecided, Disagree), reflects the traits, attitudes, values, motives and interests of students. The creativity scale was developed with the goal of identifying the highly creative personalities of individuals. The lowest score items cab receive on the scale is -2 and the highest score is 30. Levels of creativity are split into six groups which are, noncreative (<10 points), below average (10-19 points), average (20-39 points), above average (40-64 points), very creative (65-94 points), exceptionally creative (95-116). While the variance described as a result of factor analysis was calculated as 45%, the Cronbach Alpha value obtained was 0.939 (Aksoy, 2004). The Cornbach Alpha value for this study was calculated as .67. Looking at the literature, while the generally acceptable Cronbach Alpha value is .70, it is also stated that values between .60 and .70 are also acceptable (Kılıç, 2016).

2.3.3. Self-Efficacy Scale of Teaching Material Utilization

This scale, developed by Korkmaz (2011), is a 23 item 5-point Likert scale (1:Never, 2:Rarely, 3:Sometimes, 4:Very Often, 5:Always) that is made up of 3 sub-dimensions, those sub-dimensions being content, use, and design. There are 10 items in the content sub-dimension, 6 items in the use sub-dimension, and 7 items in the design sub-dimension. The KMO value calculated for factor analysis was .93, and the results of the Bartlett Test were X^2=2901.946, Sd=253, p<.001 (RMSEA= 0.055, SRMR= 0.057, GFI= 0.91, AGFI= 0.89, CFI= 0.97, NNFI= 0.96, IFI= 0.97). The Cronbach Alpha value of the scale was .822 for the scale, and .835 for the content sub-dimension, .685 for the use sub-dimension, and .620 for the design sub-dimension (Korkmaz, 2011). The Cronbach Alpha value for this study was calculated as .94 and the value for the sub dimensions of content, use, and design were .87, .79 and .87 respectively.

2.3.4. 21st Century Skills and Competences Scale Directed at Teaching Candidates

This 42 item 5-point Likert scale (1: Never, 2:Rarely, 3:Sometimes, 4:Frequently, 5:Always), was developed by Anagün, Atalay, Kilic, and Yasar (2016). This scale consists of 3 sub-dimensions which are learning and innovation skills, life and career skills, and information, media and technology skills. According to Partnership for 21st Century Skills (P21), learning and innovation skills are broken down into creativity and innovation, critical thinking and problem solving, communication and collaboration. The categories for life and career skills in the P21 are flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, leadership and responsibility. Finally, the categories for information, media and technology skills are information literacy, media literacy, and information, communications and technology literacy. The KMO value calculated for factor analysis was .843 while the Bartlett Test results were X^2=4446.655, Sd=2016, p=.00 (RMSEA= .055, NFI= .87, CFI= .93, IFI= .93, GFI= .82 and SRMR= .061). The Cronbach Alpha value of the scale was .889 and this value was calculated as .845, .826 and .810 for each sub-dimension respectively (Anagün et al., 2016). In this study, the Cronbach Alpha value was calculated as .96 and the sub-dimensions were .94, .89 and .89 respectively.

2.3.5. Opinion form

Opinion/self-evaluation forms were created by the researchers in order to gain written information before, during and after the implementation. The forms used before the implementation asked whether or not the participants felt they were adequate in design skills (no (1), somewhat (2), yes (3)) whereas the form used during the implementation asked participants to state the difficulties they faced in the implementation process and how they overcame these difficulties. The form used after the implementation asked the participants how STEM education had impacted them and the question about design skills that was asked before the implementation was reposed.

2.4. Implementation Process

The education process to ascertain the impact of STEM education on the creative design skills of prospective teachers was planned to be carried out face to face. However, it was carried out during distance learning in line with the capabilities available to the students. The implementation process proceeded with the prospective Science teachers in the Material Design in Science Education course in groups of 6, and in groups of 7 in the Probability and Statistics Education course attended by prospective Mathematics teachers. During online education, the students received information about the design-based (identifying the problem, collecting information, brainstorming solutions, picking the appropriate solution, designing and evaluating a prototype) learning that was to take place along with the design activities planned in the context of STEM education. However, the materials could not be used with the students due to distance learning. During the process, the experimental process was implemented according to instructions given to the prospective teachers (groupwork to create a STEM lesson plan for each activity, draft drawings of models for each activity created using drawing programs, individually creating models). During online classes, it was expected that the students would research the subject-scope being taught in the activities, that they would discuss the subject-scope with their group and make a prototype drawing for the problems that were being solved. In addition to doing research and drawing prototypes, active student participation was enabled by encouraging the students to use low-cost and accessible materials or household recyclables to do the activities and giving them opportunities to evaluate themselves and each other (self-evaluation form, peer evaluation rubric). The self-evaluation questions were prepared by the researchers keeping in mind the difficulties faced throughout the process and how these difficulties were overcome. The questions for evaluating their peers' homework were also prepared by the researchers, this time with a focus on use and characteristics of materials, design and scientific creativity. The STEM education program implemented for one semester is shown below (Activities were limited in order to ensure the education followed a set plan however, they designed the process according to a problem they themselves decided. Also, a two-week free design activity took place, thus encouraging the prospective teachers to think) in the Table 2:

Table 2. STEM education program.

Weeks	Activities
Weeks 1, 2, 3 and 4	General Description-Introduction (What is STEM? examples of STEM practices, how to prepare a STEM lesson plan? introduction of the STEM education process)
Week 5	Designing a Light Source
Week 6	Designing a Bridge
Week 7	Designing a Simple Machine Mechanism (Limitation: Must involve the Pascal Principle)
Week 8	Free Design (Limitation: What kind of material can we design in order to teach a subject we wish to teach in our own field? Look for an answer to this question. The material you create must be different from the activities planned for other weeks)
Week 10	Designing a Windmill
Week 12	Designing a Simple Machine Mechanism (Limitation: Must involve Compound Wheel systems) Game Design (Limitation: How can we create an educational game design for our students? Look for an answer to this question)
Week 13	Free Design (Limitation: What kind of material can we design in order to teach a subject we wish to teach in our own field? Look for an answer to this question. The material you create must be different from the activities planned for other weeks)
Week 14	Designing a Greenhouse
Week 15	City Planning Design (Limitation: What can we do to solve a problem we face in the area where we live, what kind of material can we design? Look for an answer to this question. The material you create must be different from activities planned for other weeks)

2.4.1. Pictures from the Implementation Process

Some examples of the materials designed by the participants are shown in Figure 1.

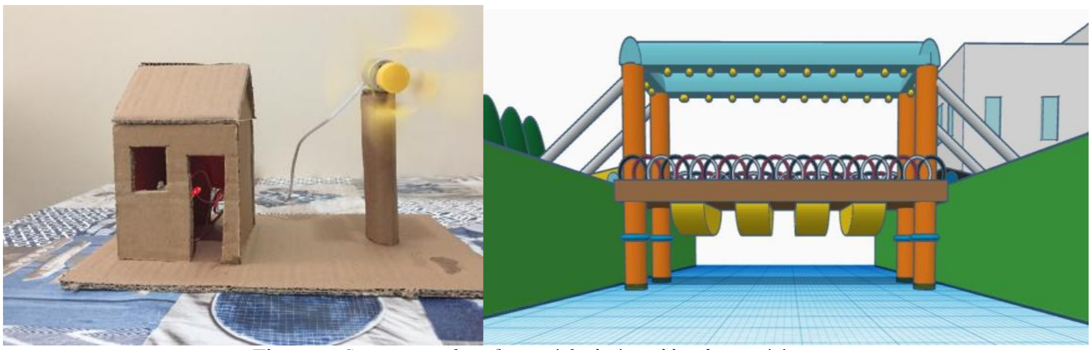

Figure 1. Some examples of materials designed by the participants.

2.5. Data Analysis

In this study, the SPSS 22.0 software package was used to analyse quantitative data. A normality test was conducted to ascertain if the data showed normal distribution. In cases where the sample size is larger than 35, the Kolmogorov-Smirnov test is used (McKillup, 2012). Aside from the Kolmogrov-Smirnov test, skewness, kurtosis values and Q-Q plot graph results were identified. Looking at the results, it was observed that the quantitative data had normal distribution. Therefore, the Dependent Sample t-Test was used in pretest-protest comparison. Descriptive analysis and content analysis was conducted for the analysis of qualitative data. In descriptive analysis, which is a type of qualitative data analysis, themes from a planned conceptual framework depending on the topic being studied are separated into codes while content analysis is the process of determining unclear themes and codes (Yıldırım & Simşek, 2018). The options method triangulation, consulting with experts, detailed description (direct quotation) were used for the persuasiveness (believability, reliability, confirmability) that must be included in the codes identified from the pre-decided themes in qualitative research (Guba & Lincoln, 1982). For the appropriacy of the themes and codes developed, the consensus criterion was paid attention to and the reliability of agreement among coders was calculated using the Reliability = Consensus / (Consensus + Disagreement) x 100 formula (Miles & Huberman, 1994). The results of the calculation identified agreement reliability as 97.1%. The disagreement seen in the codes occurred in the code of process planning under the design theme and agreement was enabled in sentences wherein the prospective teachers' opinions indirectly described the process aspect of design.

3. FINDINGS

The results featured below belong to third-year prospective teachers studying at the Department of Science Education and Department of Mathematics Education.

Table 3. Dependent sample t-test results for self-efficacy scale for stem practice.

Group	Test	N	$\bar{X}$	SD	DF	t	p
Science	Pretest	59	55.59	13.28	58	-8.016	0.000*
	Posttest	59	76.00	12.85			
Mathematics	Pretest	51	52.78	12.62	50	-6.950	0.000*
	Posttest	51	70.41	12.41			

Note: *p<.05.

Table 3 shows that according to the dependent sample t-test results of the teacher self-efficacy scale for STEM practice scale pretest posttest scores, significant change was identified (t(58)= -8.016, p=0.000; t(50)= -6.950, p=0.000) in favour of the posttest scores ($\bar{X}$=76.00; $\bar{X}$=70.41) in both groups.

Table 4. Dependent sample t-test results for how creative are you scale.

Group	Test	N	$\bar{X}$	SD	DF	t	p
Science	Pretest	59	49.20	9.87	58	-2.399	0.020*
	Posttest	59	54.88	14.49			
Mathematics	Pretest	51	50.57	10.75	50	-2.082	0.042*
	Posttest	51	55.96	14.49			

Note: *p<.05.

Table 4 shows that according to the dependent sample t-test results of the how creative are you scale pretest posttest scores, significant change was identified (t(58)= -2.399, p=0.020; t(50)= -2.082, p=0.042) in favour of the posttest scores ($\bar{X}$=54.88; $\bar{X}$=55.96) in both groups.

Table 5 shows that according to the dependent sample t-test results of the self-efficacy scale of teaching material utilization pretest posttest total scores, significant change was identified (t(58)= -8.937, p=0.000; t(50)= -4.521, p=0.000) in favour of the posttest scores ($\bar{X}$=101.79; $\bar{X}$=100.35) in both groups. Also, when each sub-dimension was analysed, significant change was identified (t(58)= -8.532, p=0.000; t(58)= -7.730, p=0.000; t(58)= -7.995, p=0.000; t(50)= -4.944, p=0.000; t(50)= -4.361, p=0.000; t(50)= -2.821, p=0.007) in favour of the posttest scores ($\bar{X}$=43.49; $\bar{X}$=26.59; $\bar{X}$=31.71; $\bar{X}$=43.65; $\bar{X}$=25.88; $\bar{X}$=30.82).

Table 5. Dependent sample t-test results for self-efficacy scale of teaching material utilization.

Group	Sub-Dimension	Test	N	$\bar{X}$	SD	DF	t	p
Science	Content	Pretest	59	36.75	5.84	58	-8.532	0.000*
		Posttest	59	43.49	5.03			
	Use	Pretest	59	22.81	3.88	58	-7.730	0.000*
		Posttest	59	26.59	2.68			
	Design	Pretest	59	27.17	4.28	58	-7.995	0.000*
		Posttest	59	31.71	3.35			
	Total	Pretest	59	86.73	12.90	58	-8.937	0.000*
		Posttest	59	101.79	10.38			
Mathematics	Content	Pretest	51	39.33	4.67	50	-4.944	0.000*
		Posttest	51	43.65	4.59			
	Use	Pretest	51	23.45	2.64	50	-4.361	0.000*
		Posttest	51	25.88	2.99			
	Design	Pretest	51	28.94	3.39	50	-2.821	0.007*
		Posttest	51	30.82	3.49			
	Total	Pretest	51	91.72	9.88	50	-4.521	0.000*
		Posttest	51	100.35	10.31			

Note: *p<.05.

Table 6. Dependent sample t-test results for 21st century skills and competences scale.

Group	Sub-Dimension	Test	N	$\bar{X}$	SD	DF	t	p
Science	Learning and Innovation Skills	Pretest	59	61.37	8.91	58	-6.880	0.000*
		Posttest	59	68.34	8.02			
	Life and Career Skills	Pretest	59	72.61	7.83	58	-7.467	0.000*
		Posttest	59	79.66	6.73			
	Information, Media and Technology Skills	Pretest	59	32.49	4.50	58	-4.841	0.000*
		Posttest	59	35.54	3.77			
	Total	Pretest	59	166.47	18.98	58	-7.535	0.000*
		Posttest	59	183.54	16.79			
Mathematics	Learning and Innovation Skills	Pretest	51	60.41	10.53	50	-2.200	0.032*
		Posttest	51	64.55	9.38			
	Life and Career Skills	Pretest	51	70.86	9.68	50	-2.370	0.022*
		Posttest	51	75.06	9.44			
	Information, Media and Technology Skills	Pretest	51	32.10	5.39	50	-2.920	0.005*
		Posttest	51	35.06	4.79			
	Total	Pretest	51	163.37	23.61	50	-2.597	0.012*
		Posttest	51	174.67	22.06			

Note: *p<.05

Table 6 shows that according to the dependent sample t-test results of the 21st century skills and competences scale directed at teaching candidates pretest posttest total scores, significant change was identified ($t(58)= -7.535$, $p=0.000$; $t(50)= -2.597$, $p=0.012$) in favour of the posttest scores ($\bar{X}$=183.54; $\bar{X}$=174.67) in both groups. Also, when each sub-dimension was analysed, significant change was identified ($t(58)= -6.880$, $p=0.000$; $t(58)= -7.467$, $p=0.000$; $t(58)= -4.841$, $p=0.000$; $t(50)= -2.200$, $p=0.032$; $t(50)= -2.370$, $p=0.022$; $t(50)= -2.920$, $p=0.012$) in favour of the posttest scores ($\bar{X}$=68.34; $\bar{X}$=79.66; $\bar{X}$=35.54; $\bar{X}$=64.55; $\bar{X}$=75.06; $\bar{X}$=35.06).

Table 7. Descriptive statistics table directed at prospective teachers' design skills.

Group	Stage	Options			Average
		No (1)	Somewhat (2)	Yes (3)	
Science	Before implementation	11 (%9.8)	32 (%28.6)	16 (%14.3)	2.08
	After implementation	1 (%.9)	22 (%19.6)	36 (%32.1)	2.59
Mathematics	Before implementation	13 (%11.6)	31 (%27.7)	7 (%6.3)	1.88
	After implementation	3 (%2.7)	28 (%25.0)	20 (%17.9)	2.33

Note: Do you feel competent about your design skills?

Table 7 shows that the average of the answers given by prospective teachers to the question on if they feel competent about their design skills was $\bar{X}$=2.08 in the Science group before implementation and $\bar{X}$=2.59 after implementation. In the Mathematics group the average was $\bar{X}$=1.88 before implementation and $\bar{X}$=2.33 after implementation. Looking at some of the options, the number of students who answered "no" or "somewhat" went down in favour of the posttest whereas there was an increase in the number of students who answered "yes".

Table 8. Prospective teachers' opinions on the impact of STEM education.

Group	Theme	Codes	Student	f
Science	Creative Thinking	Creative/creativity	(S4, S12, S13, S15, S18, S19, S20, S22, S23, S26, S27, S33, S36, S37, S39, S41, S48, S49, S55, S56, S59)	21
		New/innovative	(S1, S14, S16, S26, S41, S55, S57)	7
		Different perspective	(S3, S7, S14, S16, S18)	5
		Imagination	(S27, S44)	2
		Originality	(S27)	1
	Design	Product aspect	(S5, S6, S7, S10, S13, S14, S16, S18, S20, S24, S27, S33, S47)	13
		Process planning aspect	(S4, S46, S53)	3
Mathematics	Creative Thinking	Creative/creativity	(S1, S2, S4, S12, S13, S15, S19, S22, S24, S26, S28, S37, S47, S51, S53, S55, S59)	17
		New/innovative	(S2, S5, S6, S9, S12, S13, S20, S21, 27, S33, S56)	11
		Different perspective	(S3, S5, S6, S25, S36, S44, S50)	7
		Original/originality	(S22, S37)	2
	Design	Product aspect	(S12, S16, S17, S22, S24, S28, S36, S48, S51, S56)	10
		Process planning aspect	(S36, S45, S50)	3

When Table 8 is examined, the opinions that are thought to be related to the creative thinking and design skills researched in line with the purpose of the study are examined and mentioned in this study. Therefore, the data collected from opinions was categorised under two themes, "creative thinking" and "design". When the opinions of prospective Science teachers were examined, the following were mentioned by the number of students stated in parentheses: "creative/creativity" (21), "new/innovative" (7), "different perspective" (5), "imagination" (2), "originality" (1), "product aspect" (13), "process planning aspect" (3). Looking at the opinions of the prospective Mathematics teachers, the following were mentioned by the number of students stated in parentheses: "creative/creativity" (17), "new/innovative" (11), "different perspective" (7), "original/originality" (2), "product aspect" (10), "process planning aspect" (3). Examples of quoted statements are given below.

S41(Science): "I developed my problem solving and creative thinking skills with STEM education. I realised that I could create new inventions when faced with problems."

S1(Science): "During the Stem education, being able to create things from nothing or add innovation to something that already exists on a given subject was interesting to me."

S16(Science): "It enabled us to come up with different ideas to develop something when an idea is presented in terms of practical thinking and project development."

S27(Science): "I learnt to think critically and creatively, and what kind of path I need to take when faced with a problem. I used my imagination and created original designs."

S47(Science): "It helps me to design materials."

S4(Science): "Before there were thinks we did not pay attention to when preparing a design or a lesson plan however, after receiving STEM education there was a difference for example, we actually used engineering in this part or technology in this part."

S2(Math): "I think it is very interesting to combine learning outcomes aimed at many subjects while also creating something new."

S6(Math): "It pushes one to think differently, to create new things."

S37(Math): "It contributed quite a bit to adding originality and creativity and it will continue to do so."

S16(Math): "It is quite interesting to create a product and that it is related to many fields."

S50(Math): "By listening to the projects my friends created, I was able to see different sides of an event. I learnt the stages of creating a project, I developed myself in the field of design."

When Table 9 is examined, it was identified that the prospective students faced various difficulties during the education process. When the opinions of prospective Science teachers were examined, the following difficulties were mentioned by the number of students stated in parentheses: "acquiring materials" (35), "drawing on the drawing program" (18), "coming up with ideas" (14), "making material components functional" (11), "lack of time" (10), "lapses in group communication" (10), "insufficient internet connection" (2). The prospective Science teachers described the following as solutions: "exchange of ideas (researcher, groupmate, family member, neighbour)"(35): "using reasoning (through research, trial and error)" (35). Looking at the opinions of the prospective Mathematics teachers, the following difficulties were mentioned by the number of students stated in parentheses: "drawing on the drawing program" (10), "coming up with ideas" (7), "making a decision" (6), "technical difficulties" (5), "acquiring materials" (4), "lack of time" (4), "making material components functional" (3), "insufficient internet connection" (3), "identifying learning outcomes/planning" (2). The prospective Mathematics teachers described the following as solutions: "exchange of ideas (groupmate)" (12), "using reasoning (through research)" (2). Also, prospective teachers in both groups except for those listed in the tables (Table 8 and Table 9), stated that they did not experience any problems during the process while some stated that they faced difficulties but did not give any information about the solution and others did not express any opinions.

S2(Science): "I had issues with the motor because of the stay-at-home orders and the fact that my house is far from the stationary store, but I showed its implementation."

S9(Science): "It is very difficult to draw in the Tinkercad drawing program and because it is a very time consuming process I found it difficult to draw."

S22(Science): "It was difficult to come up with an original idea that had never been thought of before. However, we were able to come up with original ideas through group discussions."

S1(Science): "Since I made my model out of pasta, I had a lot of trouble putting the pasta together. I later solved my problem by tying the pasta in many places using string."

S49(Science): "We had trouble in groupwork. The meetings were disjointed. This happened because we had internet issues. We also had limited time. Unfortunately, we could not solve the internet problems experienced by our friends."

S54(Science): "It was somewhat difficult to communicate with our groupmates remotely. However, we solved the problem by communicating with each other at a set time."

S40(Science): "We did not experience any big problems because we divided the labour. I could not find the balloon necessary for modelling and I needed to send it emergently. I used a plastic bag instead of a balloon."

S18(Math): "I had difficulty making 3 dimensional drawings in some cases however, the videos I watched and certain works I examined helped me overcome this issue."

S10(Math): "It can sometimes be difficult finding a time when everyone is available to work at the same time because everyone's home life is different and they may not see the messages immediately. This is why we try to decide what time we will meet a day in advance."

S23(Math): "It was challenging to come up with an original idea. We found an idea by brainstorming."

S30(Math): "We had quite a bit of hesitation about the originality of our ideas in this activity and we also had differences of opinion in the applicability however, because we believed it needed to be presented as a project and that its shortcomings needed to be discussed in terms of literature, we tried to develop it by adding more original ideas."

S12(Math): "Due to internet and computer issues, we had trouble communicating with our friends and occasionally not being able to understand each other. The reason for this problem was our computers freezing as we were using our computers and the internet excessively due to distance learning, the tinkercad program was lagged after we finished the project and our project almost got deleted and we saved it at the last moment."

Table 9. Difficulties faced by prospective teachers and the solutions.

Group	Theme	Codes	Student	f
Science	Difficulties faced in the education process	Acquiring materials	(S1, S2, S4, S7, S9, S10, S11, S12, S13, S15, S16, S17, S18, S20, S21, S22, S23, S25, S26, S29, S30, S31, S32, S37, S39, S40, S41, S43, S44, S45, S46, S48, S50, S51, S55)	35
		Drawing on the drawing program	(S5, S7, S8, S9, S13, S17, S19, S20, S24, S28, S29, S33, S35, S41, S43, S45, S46, S47)	18
		Coming up with ideas	(S6, S9, S10, S11, S18, S22, S24, S27, S28, S30, S31, S34, S36, S54)	14
		Making material components functional	(S1, S2, S13, S22, S27, S30, S36, S39, S40, S51, S55)	11
		Lack of time	(S1, S3, S4, S9, S13, S17, S18, S19, S49, S53)	10
		Lapses in group communication	(S12, S13, S17, S21, S25, S26, S38, S49, S53, S54)	10
		Insufficient internet connection	(S13, S49)	2
	Solution	Exchange of ideas (researcher, groupmate, family member, neighbour)	(S1, S2, S5, S6, S7, S8, S9, S10, S11, S13, S17, S18, S19, S20, S22, S24, S27, S28, S29, S30, S31, S33, S34, S35, S36, S39, S40, S41, S43, S45, S46, S47, S51, S54, S55)	35
		Using reasoning (through research, trial and error)	(S1, S2, S5, S6, S7, S8, S9, S10, S11, S13, S17, S18, S19, S20, S22, S24, S27, S28, S29, S30, S31, S33, S34, S35, S36, S39, S40, S41, S43, S45, S46, S47, S51, S54, S55)	35
Mathematics	Difficulties faced in the education process	Drawing on the drawing program	(S4, S6, S11, S17, S18, S24, S27, S29, S37, S38)	10
		Lapses in group communication	(S3, S7, S10, S12, S15, S17, S21, S26, S28, S32)	10
		Coming up with an idea	(S2, S8, S13, S22, S23, S34, S36)	7
		Making a decision	(S5, S19, S25, S29, S30, S39)	6
		Technical difficulty	(S9, S12, S15, S21, S32)	5
		Lack of time	(S3, S10, S14, S27)	4
		Making material components functional	(S31, S36, S37)	3
		Insufficient internet connection	(S7, S12, S21)	3
		Identifying learning outcomes	(S13, S16)	2
		Acquiring materials	(S7, S14)	2
	Solution	Exchange of ideas (groupmate)	(S2, S4, S5, S6, S8, S11, S17, S24, S22, S23, S29, S38)	12
		Using reasoning (through research, trial and error)	(S18, S31)	2

S14(Math): "It was challenging to try to create a project that was technological, efficient and useful all at once while also being low-cost. I think we should have a material in order to develop a design. The time provided for the homework was also limited."

S31(Math): "While designing the structures in Tinkercad, we found it difficult to arrange the directions of the structures because it was 3 dimensional. A structure that looked good from one angle did not look good from another. So, we reached a proper alignment by trying different angles."

S13(Math): "We found it hard to think of what we could do apart from normal greenhouse lighting. We found how we should approach it from an engineering standpoint difficult. We found it difficult to find appropriate learning outcomes."

S5(Math): "We spent a long time thinking about which of the ideas we found we were going to do in the end we reached a consensus on this design."

4. DISCUSSION

In this study, the impact of STEM education on the creative design skills of prospective teachers was investigated and interpretations were made in line with the data obtained.

Looking at the comparison of prospective teachers' pretest-posttest total and sub-dimension scores examined within the scope of the first sub-problem of the study, significant change in favour of the posttests was identified in all scales in both groups. This lead to the conclusion that the design based STEM education offered can increase prospective Science and Mathematics teachers' teacher self-efficacy, creativity, self-efficacy in utilising teaching materials (content, use, design) in STEM implementations, and their self-efficacy in 21st century skills (learning and innovation skills, life and career skills, information, media and technology skills. In addition, when the quantitative data obtained was examined, the answers given by prospective teachers before and after the implementation to the question "Do you feel competent in your design skills?" were looked at descriptively and when pre and post implementation averages were compared, an increase was found in favour of the post-implementation answers. This supports the increase in self-efficacy in utilising teaching materials that encompasses the creating, using and designing materials sub-dimension that involves materials. There are studies that support the findings of this study (Bozkurt & Tan, 2020; Cetin & Kahyaoğlu, 2018; Kendaloglu, 2021; Sarac & Doğru, 2021). In Bozkurt and Tan (2020) study in which they examine creativity in design-based learning in STEM education that they conducted on middle school students; they reached the conclusion that design based learning is important for developing creativity. Cetin and Kahyaoğlu (2018), in their study on the impact of STEM based activities on prospective Science teachers' attitudes on 21st century skills, found that positive attitudes about 21st century skills increased at the end of the implementation. Kendaloglu (2021) researched the impacts of the process of developing a STEM activity on the STEM self-efficacy of prospective Science teachers, and came to the conclusion that engineering design-based, problem-centric and project-based STEM activities increase STEM self-efficacy. In their study in which they examined classroom teachers' experiences of STEM education design and implementation, Sarac and Doğru (2021) found that the STEM education that took place positively impacted the perceived self-efficacy of the prospective teachers. The prospective teachers also expressed positive opinions about the design and implementation process. Arslanhan and Inaltekin (2019), in their study on the impact of design-based learning implementations on the STEM understanding of prospective Science teachers, concluded that design-based learning activities had a positive impact on developing creativity and other STEM competences, while also discussing how prospective teachers at the undergraduate level did not possess enough information and skill to use STEM with design-based activities and stated that they should be supported. Kim, Oliver, and Kim (2019), in their study in which they aimed to develop the engineering design and teaching knowledge of prospective Science teachers, stated that prospective teachers' creative and systematic thinking skills can experience positive change within the scope of engineering design activities.

It was asked what effects the STEM education could have on the prospective teachers, and, in line with the purpose of the study, the data was analysed under two themes, "creative thinking" and "design". According to the answers of the prospective Science teachers, it was observed that the codes "creative/creativity", "new/innovative", "different perspective", "imagination", "originality" emerged. In the design themes, the codes "product aspect" and "process planning" were obtained. Looking at the prospective Mathematics teachers' answers, the codes that emerged in the creative thinking theme were "creative/creativity", "new/innovative", "different perspective", "original, originality" whereas the codes identified in the design theme were aimed at "product aspect" and "process planning". It was observed that the findings of this study overlap with imagination that is under the process dimension of scientific creativity, originality and flexibility under the trait dimension and technical product aspect described in a three-dimensional model in Hu and Adey (2002) study targeted at the scientific creativity test for middle school students. It was also observed that the prospective teachers used the term creativity directly most frequently, followed by the term innovative. According to these results, it can be said that the implementation that took place had a positive impact on creativity and design skills.

In addition, the difficulties faced by prospective teachers in the education process and the solutions they found to overcome these difficulties were asked and looking at the codes identified as a result of the answers given by prospective Science teachers, the codes, in order of most to least frequent were as follows: "acquiring materials", "drawing on the drawing program", "coming up with ideas", "making the material components functional", "lack of time", "lapses in group communication", "insufficient internet connection" were seen as difficulties. Looking at the codes obtained as a result of the answers given by prospective Mathematics teachers, the codes, in order from most to least frequent were as follows "drawing on the drawing program", "lapses in group communication", "coming up with an idea", "making a decision", "technical difficulty", "lack of time", "making the material components functional" "identifying learning outcomes/planning", "acquiring materials" were seen as difficulties. Insofar as solutions, it was identified that both groups used "exchange of ideas" and "using reasoning", and it was observed that they could apply these solutions apart from to overcome the difficulties "lack of time" and "insufficient internet connection". Bakırcı and Kaplan (2021) in their study on the difficulties faced by science teachers in the field of engineering and design skills and potential solutions, mentioned that the teachers were lacking in technical tools when it comes to engineering and design skills, and that they felt they were lacking in three-dimensional modelling. While this supports the topic of lack of materials faced in this study, it also puts forth the teachers' shortcomings insofar as drawing. The Ministry of Education (2018) has stated that the changes in science and technology, the changing needs of society has impacted the characteristics that individuals must possess. The Ministry described these traits as creating information, making it functional, being able to make decisions, being able to communicate etc. As is clear from this statement, when the findings are interpreted, it was identified that individuals are not competent enough in the traits that they must possess, and it can be said that the implementation process provided a good environment for the acquisition of these traits, as suggested by the fact that "exchange of ideas" and "using reasoning" were stated as solutions utilised by the participants. In their study, Bakırcı and Kaplan (2021) also found that Science teachers reported making use of the Mathematics, Visual Arts, Information Technologies, Turkish, Technology and Design fields in engineering and design skills implementations. In line with this, it can be thought that learning outcomes can be created in an interdisciplinary fashion, and that prospective teachers who struggle to create learning outcomes must be supported. It can be thought that utilising information from various disciplines in a way that creates cooperation within and between different disciplines, the problem of making material components functional can also be overcome.

5. CONCLUSION

This study is limited by the sample groups in the implementation, the single group pretest posttest model, the implementation carried out (STEM implementations with design-based learning), the data collection tools used and the opportunities provided by the compulsory distance learning process underwent by the prospective teachers. Also, the redesign and finalisation of the decision stages included in design-based learning according to Hynes et al. (2011), could not be carried out due to difficulties that arose. Another noteworthy issue is that, in STEM education, which includes the field of engineering, while the engineering design process creates an environment for developing science and mathematics content information (Cepni, 2018; Kolodner, 2002), this study focused more on design skills. In STEM integration, in which scientific inquiry and engineering design processes are included, design process implementations done without scientific inquiry are not in line with the structure of STEM education (Cepni, 2018). Therefore, the study took place without ignoring this fact. In line with the results obtained, it can be said that with the STEM education carried out, teacher self-efficacy can be enhanced in both groups, thus enabling the environment for STEM implementations to take place, that the implementation carried out is a design process at the end of which a product is obtained, and that it enhances creativity, which is both one of the design skills and 21st century learning and innovation skills. It can be said that the STEM education carried out can be implemented with prospective teachers who will become instructors of Science and Mathematics, which are components of STEM, and that the implementation of this education has a positive impact of creative design skills. In addition, it was observed that the prospective teachers did not state any negative opinions, except for acquiring materials, internet connection issues and technical difficulties, in this study that was intended to be carried out face to face in a laboratory setting, but was instead implemented during distance learning necessitated by the pandemic. If the problems faced are solved, it can mean that design-based STEM implementations can be carried out via distance learning.

6. SUGGESTIONS

1. In line with the STEM education carried out, implementations that examine creativity and design skills can be carried out with prospective teachers from other fields, primary and middle school students, and the results of such implementations can be observed.
2. It can be highlighted that not only product production but also process design are within the scope of design skills.
3. Inter-disciplinary implementations that encourage teachers to come up with ideas can be carried out or the number of such implementations can be increased.
4. Individuals can be encouraged to take part in group activities, thus increasing interpersonal communication and enabling them to work cooperatively.
5. Prospective teachers can be encouraged to learn to use software such as drawing programs that they will use in the education process or prospective teachers can be offered training on this subject.
6. Environments in which prospective teachers can work in collaboration with experts from different disciplines in interdisciplinary implementations to create learning outcomes can be created.
7. Data collection tools, in which creativity and design skills can be measured in one place, can be developed.

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