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An Interdisciplinary Renewable Energy Education: Investigating the Influence of STEM Activities on Perception, Attitude, and Behavior

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ABSTRACT The study aimed to examine the effects of design-based STEM activities developed for renewable energy sources on science teacher candidates' perceptions, attitudes, and behavioral orientations. The one-group pretest-posttest design was used. The participants comprised 40 second-grade teacher candidates studying at a public university, and the study lasted for 14 weeks. The data were collected using a renewable energy perception scale, renewable energy sources attitude scale, sustainable consumption behavior scale, and STEM product-performance observation form. The results demonstrated that design-based STEM activities towards renewable energy sources enhanced teacher candidates' perception, attitude, and behavior toward renewable energy sources. However, there was no statistically significant increase in the unneeded consumption sub-dimension of the sustainable consumption behavior scale and the renewable energy-environment relationship sub-dimension of the renewable energy perception scale.

Keywords Attitude, Behavior, Perception, Renewable Energy, STEM education

1. INTRODUCTION

Interest in science and mathematics is decreasing daily worldwide (National Research Council [NRC], 2014). Studies have shown that traditional approaches are not enough to increase the interest in science education again and that it is not enough to include only field-specific information in science lessons and need innovative approaches to motivate and interest students (Vedder-Weiss & Fortus, 2012). Similarly, students' interest in mathematics and science gradually decreases (Akgündüz, 2016). The United States of America (USA), one of the countries that wanted to overcome this problem, laid the foundations of an interdisciplinary approach to undergraduate education in the 1990s. The National Science Foundation (NSF) has implemented a new approach (SMET - Science, Mathematics, Engineering, and Technology) that combines science, mathematics, technology, and engineering. In the 2000s, this approach started to be named STEM (Science, Technology, Engineering, and Mathematics). In this approach, in addition to teaching the subject, the content taught is practical and is done from an engineering point of view (Sanders, 2009).

STEM education will improve students' interest in science and mathematics disciplines in the curriculum prepared in recent years in many leading world countries such as the USA, Australia, and England (NRC, 2014). One of these programs, the curriculum prepared in the USA, focused on students not only thinking like a scientist but also producing by seeing themselves as an engineer, and gathered science education around eight main actions. These actions can be listed as follows; asking questions (as a candidate scientist) and defining the problem (from an engineer's perspective), developing and using a model, planning and performing experiments, analyzing and interpreting data, being able to think mathematically and operationally, developing arguments (as a candidate scientist) and solution (from an engineer's perspective), developing arguments using data, acquiring knowledge, and evaluating and sharing (NRC, 2012). In Turkey, as a reflection of these studies, innovations have been made toward a scientific thinking-oriented approach in the curricula published in 2017 (Ministry of National Education [MoNE], 2017) and updated in 2018. Science, Engineering, and Entrepreneurship Practices and the engineering dimension were tried to be integrated into the curriculum. The engineering and entrepreneurship skills have been added to the scientific process and life skills discussed in previous curriculums. The curriculum defines

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this situation: "Students are expected to describe a daily need or problem related to the topics covered in the units. It is desired that the problem is aimed at improving the tools, objects, or systems used or encountered in daily life. In addition, the problems should be handled within the scope of material, time, and cost criteria" (MoNE, 2018).

1.1 Theoretical Framework of the Research

Researchers have some concerns and suggestions about implementing STEM education and integrating science, technology, mathematics, and engineering fields. For example, a technology educator may encounter limitations in integrating science and mathematics disciplines into his courses (Sanders, 2009). In this case, the literature recommended that integrating science and mathematics disciplines and adding technology and engineering (design process) fields to these fields will help realize a more effective and beneficial STEM course and practice (Çorlu, Capraro, & Capraro, 2014). It is to integrate at least two of these disciplines in STEM education and understand that employing specific knowledge and skills in only one discipline for STEM education is not correct. STEM education aims to make students individuals who can solve real-world problems, look at problems from an interdisciplinary perspective, understand the nature of technology, think systematically, inquire, have high self-confidence, and are open to communication and creativity (Bybee, 2010; Şahin, Ayar, & Adıgüzel, 2014).

Teachers' perspectives on STEM, their field knowledge, and their knowledge of other disciplines are significant in integrating STEM disciplines (Ríordáin, Johnston, & Walshe, 2016). However, considering the related literature, teachers have negative perceptions of STEM (Coffey & Alberts, 2013), inadequate self-efficacy perceptions that they can integrate STEM disciplines (Ross, Beazley, & Collin, 2011), and insufficient knowledge about STEM (Akaygün & Aslan-Tutak, 2016). Also, it is difficult for teachers to integrate STEM disciplines into their classrooms (Guzey, Harwell, & Moore, 2014). For this reason, teachers and candidates must understand the nature of STEM practices and experience them (Adams, Miller, Saul, & Pegg, 2014; Guzey et al., 2014). Teachers who understand the nature of STEM practices and experience them personally will be able to provide the support their students will need (English, Hudson, & Dawes, 2012; Ríordáin et al., 2016). While the skills of teachers to integrate STEM disciplines with in-service training programs have improved (Moore et al., 2014), teacher candidates need to experience the process of integrating STEM disciplines with various courses and practices during undergraduate education.

STEM activities can be applied in many subject areas. One of them is renewable energy sources. Renewable energy sources are shown as an alternative to rapidly depleting fossil fuels, and it is also predicted that they will reduce greenhouse gases caused by fossil fuel use (Liarakou, Gavrilakis, & Flouri, 2009). Increasing the orientation towards renewable energy is possible by increasing the awareness of individuals on this issue (Liarakou et al., 2009; Özmen & Karamustafaoğlu, 2006). At this point, the necessity of increasing the knowledge level of teachers and teacher candidates and positively changing their attitudes emerge. Thus, teachers can reflect their knowledge and attitudes on their lessons (Liarakou et al., 2009). Studies have reported that teacher candidates and teachers have positive attitudes toward renewable energy sources (Genç, 2019; Yenice & Alpak Tunç, 2018; Zyadin, Puhakka, Aphonen, & Pelkonen, 2014). However, teachers and candidates have limited knowledge of renewable energy sources (Cebesoy & Karışan, 2017; Karakaya Cirit, 2017; Saraç & Bedir, 2014; Zyadin et al., 2014). The practices for design-based activities about renewable energy sources increase teacher candidates' awareness of this issue (Uysal & Cebesoy, 2020). Therefore, design-based STEM practices are necessary to improve teacher candidates' perception levels, attitudes, and behaviors toward renewable energy sources.

The increase in individuals' perception, attitude, and behavior levels about renewable energy is the most critical factor in the formation of preferences by adopting the subject. As individuals' perceptions and attitudes towards renewable energy increase positively, they will be able to acquire positive behaviors in this regard, and the use of different energies related to renewable energy will be carried out efficiently. Teaching this through design-based activities such as STEM will enable pre-service teachers to show positive perceptions, attitudes, and behaviors towards renewable energy. When they become teachers in this situation, they can provide their students with a classroom environment for STEM-based renewable energy sources.

1.2 The Importance of Research

The region where this study was carried out is rich in renewable energy resources. It is possible to see almost all types of renewable energy, such as geothermal energy, biomass energy, solar energy, and wind energy, in the region. For example, 20 of 31 geothermal power plants operating in Turkey are within the borders of this region. It also has a total of nine wind farms in the region, and the sun, which shows its hot face in the region 305 days a year, makes the region a center of attraction in terms of renewable energy sources. This situation necessitates explaining renewable energy's regional and global importance to the public and raising awareness of this issue. In order to raise awareness of renewable energy in future generations, the most important content is in the science courses where these topics are included, and the greatest responsibility belongs to the science teachers, who are the instructors of this course. Therefore, this study tried to reveal the pre-service science teachers' participation in an application about STEM-based renewable energy sources and teacher candidates' perceptions, attitudes, and behaviors about renewable energy.

In addition to the necessity of increasing the perceptions, awareness, and attitudes of teacher candidates about renewable energy sources, it is also necessary for teacher candidates to understand the nature of STEM practices and gain experience in STEM practices (English et al., 2012; Ríordáin et al., 2016). In this case, teacher candidates' perceptions, attitudes, and awareness about renewable energy sources can be improved through STEM activities. Some studies use STEM activities on renewable energy sources (Çevik, 2018; Marulcu & Höbek, 2014). For example, STEM activities based on engineering design (Marulcu & Höbek, 2014) and project-based STEM activities (Çevik, 2018) successfully improved teacher candidates' knowledge levels about renewable energy sources. Furthermore, considering that design-based activities develop many skills such as high-level thinking, problem-solving, and decision-making skills (Bozkurt Altan, Yamak, Buluş Kırıkkaya, & Kavak, 2018; Hacıoğlu, Yamak, & Kavak, 2017), it becomes necessary to examine the effect of design-based STEM activities developed on renewable energy sources. However, the lack of a comprehensive study examining the effects of design-based STEM activities developed for renewable energy sources on the perception, attitude, and behavioral orientations of science teacher candidates in the relevant literature constitutes the starting point of this study. Based on this, answers to the following research questions were investigated:

(1) Are there any significant differences between pre-test and post-test scores on the perception of renewable energy sources of science teacher candidates who received design-based STEM activities about renewable energy sources?

(2) Are there any significant differences between pre-test and post-test scores on the attitude about renewable energy sources of science teacher candidates who received design-based STEM activities about renewable energy sources?

(3) Are there any significant differences between pre-test and post-test scores on the behavior of science teacher candidates who received design-based STEM activities about renewable energy sources?

2. METHOD

The one-group pre-test and post-test experimental design was utilized in this study (Fraenkel, Wallen, & Hyun, 2012). This study decided to use this design because it aimed to examine the effect of design-based STEM activities, and there was no control group in the study. The reason why there was no control group in the study is that the researcher wanted to include all second-year teacher candidates in the study. Another reason for not having a control group in the study is that the syllabus of the pre-service teachers and the number of students are not suitable for dividing the course. It is necessary to increase the awareness of pre-service teachers about STEM education so that they can include the development of engineering and design skills, which are emphasized in the current science curriculum, in their lessons. This is possible with educational practices (Charleston & Leon, 2016; McDonald, 2016).

For this reason, the researchers included all pre-service teachers who took the course in this study. Before and after the STEM integrated alternative energy sources course, the renewable energy sources attitude scale, renewable energy perception scale, and sustainable consumption behavior scale were used as pre-test and post-test for undergraduate students to examine attention and perception toward renewable energy and sustainable consumption behavior. STEM-based renewable energy sources courses were administered to students during the whole semester. Presentations about falling water (hydroelectric sources), wind, solar energy, plant materials (biomass), the heat of the earth (geothermal), waves, ocean currents, and energy of tides were presented to improve students' knowledge about renewable energy sources. Also, sample activities and presentations about the engineering design process were made to improve the STEM design abilities of students.

2.1 Participants

The study group consisted of forty undergraduate students (twenty-nine female and eleven male) studying in the science teaching department at a state university in the Aegean Region and taking the Alternative Energy Sources course. It has been observed that the ages of teacher candidates vary between 19-22 years. Researchers used the convenient sampling method while determining the study group. This method uses the most appropriate sample group in terms of time and costs to obtain rich data about a particular situation (Patton, 1990). Participants generally consist of students from surrounding provinces. Students worked in groups of four while designing STEM products about renewable energy resources. Students participated in the study entirely voluntarily and determined their study groups. Students in the sample were selected based on voluntariness, with the readily accessible sampling method, for undergraduate students who attended a current elective course.

2.2 Data Collection Tools

Renewable energy perception scale

The original form of the scale was improved by Yakut İpekoğlu, Üçgül, and Yakut (2014). This scale aimed to decide university students' perceptions of renewable energy sources. The scale included 25 items with a 5-point Likert type. Four adapted scale-scale sub-scales were renewable energy knowledge, renewable energy-environment relationship, renewable energy future vision, and renewable energy tendency. Cronbach alpha coefficients for the overall scale (α = .80) and renewable energy knowledge (α

= .84), renewable energy - environment relationship (α = .80), renewable energy future vision (α = .70), and renewable energy tendency (α = .87) were calculated. For the data to be relevant for factor analysis, the KMO value is expected to be more than .60, and the Bartlett sphericity test should be significant (Field, 2013; Pallant, 2020). The result of the data analysis showed that the KMO value was .79; the Bartlett sphericity result was statistically significant ($p < 0.001$). Based on the results, it can be said that the data are relevant for factor analysis.

Renewable energy sources attitude scale

The original form of the scale was improved by Güneş, Alat, and Gözüm (2013). This scale aimed to decide the attitudes of science and technology candidate teachers about renewable energy sources. The scale included 26 items with a 5-point Likert type. Four adapted scale-scale sub-scales were application request, the importance of education, country interest, environmental awareness, and investments. Cronbach alpha coefficients for the overall scale (α = .89) and application request (α = .78), the importance of education (α = .74), country interest (α = .80), and environmental awareness and investments (α = .70) were calculated. The result of the data analysis showed that the KMO value was .87; the Bartlett sphericity result was statistically significant ($p < 0.001$). Based on the results, it can be said that the data are relevant for factor analysis.

Sustainable consumption behavior scale

The original form of the scale was improved by Doğan, Bulut, and Kökalan Çımrın (2015). This scale aimed to decide the sustainable consumption behavior of individuals. The scale included 17 items with a 5-point Likert type. Four adapted scale-scale sub-scales were environment, unneeded consumption, savings, and reusability. Cronbach alpha coefficients for the overall scale (α = .86) and environment (α = .91), unnecessary consumption (α = .84), savings (α = .89), and reusability (α = .79) were calculated. The result of the data analysis showed that the KMO value was .84 the Bartlett sphericity result was found to be statistically significant ($p < 0.001$). Based on the results, it can be said that the data are relevant for factor analysis.

2.3 Data analysis

While quantitative data were analyzed with the Wilcoxon test and paired sample t-test, qualitative data was utilized with descriptive analysis. Renewable energy sources attitude scale for science teachers, renewable energy perception scale, and sustainable consumption behavior scale were used at the implementation period's beginning and end. The normality test was performed as the Shapiro-Wilk test to determine whether the scores followed the normal distribution (Pallant, 2020). Normality test results proved that the data show the normal distribution for renewable energy knowledge, renewable energy-environment relationship, renewable energy future vision, the importance of education, country interest, environmental awareness and investments, environment

Table 1 Normality test results for Renewable Energy Perception Scale and sub-scales

Scale and subscales	Statistic	df	*p*
Pretest-RE perception scale	.971	40	.389
Posttest-RE perception scale	.971	40	.389
Pretest-RE Knowledge	.966	40	.257
Pretest-RE - Environment Relationship	.975	40	.521
Pretest-RE Future Vision	.948	40	.063
Pretest-RE Tendency	.923	40	.009
Posttest-RE Knowledge	.966	40	.257
Posttest-RE-Environment Relationship	.975	40	.521
Posttest-RE Future Vision	.948	40	.063
Posttest-RE Tendency	.923	40	.009

RE = Renewable energy

Table 2 Normality test results for Renewable Energy Sources Attitude Scale and sub-scales

Scale and subscales	Statistic	df	*p*
Pretest-Renewable energy sources attitude scale	.966	40	.271
Posttest-Renewable energy sources attitude scale	.966	40	.271
Pretest-application request	.940	40	.036
Pretest-the importance of education	.963	40	.217
Pretest-country interest	.954	40	.107
Pretest-environmental awareness and investments	.970	40	.358
Posttest-application request	.940	40	.036
Posttest-the importance of education	.963	40	.217
Posttest-country interest	.954	40	.107
Posttest-environmental awareness and investments	.970	40	.358

Table 3 Normality test results for Sustainable Consumption Behavior Scale and sub-scales

Scale and subscales	Statistic	df	*p*
Pretest-Sustainable consumption behavior scale	.974	40	.470
Posttest-Sustainable consumption behavior scale	.974	40	.470
Pretest-environment	.948	40	.064
Pretest-unneeded consumption	.943	40	.044
Pretest-savings	.935	40	.024
Pretest-reusability	.941	40	.038
Posttest-environment	.948	40	.064
Posttest-unneeded consumption	.943	40	.044
Posttest-savings	.935	40	.024
Posttest-reusability	.941	40	.038

Table 4 Overview of STEM activities and relationships of STEM disciplines

Activity	Science	Technology	Engineering	Mathematics
Recycled Car	Understanding and application of recycled materials and force of air pressure	Using recycled materials, designing wheels, vehicle body types, and other components	Designing of recycled car	Measurement and calculations of force, air pressure, and motion
Solar Powered Street Lamp Model	Understanding the importance of electrical energy	Understanding the function and efficiency of the solar panel	Designing a street lamp model using an LED lamp and solar panel	Measurement and calculations involving Ohm's Laws
Solar Car	Electrical and mechanical energies	Understanding of solar panels and motor	Designing a solar car	Measurement and calculations of motion and energy
Solar Oven	Temperature and heat energy	Understanding of space technology	Designing a heat-conserving solar oven	Calculating the relationship between temperature and time under sunlight
House model illuminated by wind energy	Understanding the importance of wind energy	Designing a sustainable house model in terms of electrical energy	Designing a house model illuminated by wind energy	Measurement and calculations about wind energy, daily electric power demand for a home
Water Tribune Model	Transformation of water energy to electrical energy	Understanding the function and mechanism of the water tribune and micro-generation	Designing an efficient water turbine	Measurement and calculations involving the flow rate
Hydroelectric Energy Activity	Understanding the effect of water pressure and gravity	Understanding the function and limitations of the hydroelectric power plants	Designing a hydroelectric power plant model that can reach the highest efficiency	Measurement of the rate of water pressure and electricity
Geothermal energy activity	Understanding the effect of vapor pressure and electricity	Understanding the function and limitations of the geothermal power plants	Designing a geothermal power plant model that will operate using steam energy	Measurement of the rate of vapor pressure and electricity
Wind turbine activity	Understanding the importance of wind energy and the effect of a wind turbine on endangered living	Understanding of function and limitations of the wind tribune and other technological solutions about wind tribune for endangered living	Designing a product to save lives, such as birds from wind tribune	Measurement and calculations of wind turbine and a living area of endangered livings.
Biomass energy activity	Understanding the biomass energy	Understanding the function and limitations of biomass power plant	Designing biomass in which they will find out what materials the biomass should consist of that will release the most biogas	Measurement of the rate of biogas and biomass energy

sub-scales, and comprehensive data from the renewable energy perception scale, renewable energy sources attitude scale and sustainable consumption behavior scale. On the other hand, normality test results proved that the data do not show the normal distribution for renewable energy tendency, application request, unneeded consumption, savings, and reusability sub-scales (Table 1, Table 2, and Table 3).

The researcher observed the process of developing STEM products, designed products, and group work and noted the data. Teacher candidates were evaluated regarding group evaluation, design process , the end product's functionality, and the end product's evaluation. In addition, supplementary field notes and observation dialogues between teacher candidates were recorded. The data were transferred to the computer environment and then analyzed with the content analysis technique. The collected field notes and dialogues were also controlled and collected by another field expert during the implementation process. Data from the researcher's field notes were compared with other field experts. The field expert

Table 5 Paired sample t-test results

Scale and subscales	N	$\bar{X}$	SD	DF	t	*p*	*d*
Post-test - Renewable energy perception scale	40	3.76	.48	39	9.93	.00	1.57
Pre-test - Renewable energy perception scale	40	2.24	.48				
Post-test - Renewable energy knowledge	40	4.25	.41	39	19.45	.00	3.07
Pre-test - Renewable energy knowledge	40	1.75	.41				
Posttest-Renewable energy-environment relationship	40	2.92	.70	39	-.77	.45	.12
Pre-test - Renewable energy-environment relationship	40	3.09	.70				
Post-test - Renewable energy future vision	40	3.85	.53	39	10.22	.00	1.62
Pre-test - Renewable energy future vision	40	2.15	.53				

Table 6 Wilcoxon test results

Subscale		N	Mean Rank	Sum of Ranks	*z*	*p*	*r*
Pre-test renewable energy tendency – post-test renewable energy tendency	Negative Ranks	37	19.95	738.00	-5.35	.00	.60
	Positive Ranks	1	3.00	3.00			
	Ties	2					
	Total	40					

supported a complete agreement between the data and the accuracy of the field notes.

2.4 Instructional design

The implementation of design-based STE M activities lasted for the entirety of a one-term undergraduate renewable energy resources course. Teacher candidates were informed about the STEM approach and engineering design process at the beginning renewable energy resources courses. This information process aims to check whether there are deficiencies in the previous education of the teachers and to correct any misconceptions about STEM education. After that, the researcher made presentations about alternative and renewable energy sources, which are the course content, and how they are used. Then, some examples of daily life problems were given to participants to design STEM projects. Finally, they would make STEM projects about the theme of alternative energy sources. In addition, participants were allowed to design STEM projects based on alternative energy sources, which they could suggest themselves. At the end of the five-week process of designing STEM projects with the theme of alternative energy sources, all groups made promotional videos for their products and tried to present and evaluate them in front of the class. The participants, who started their presentations by explaining the problems they set out and the context of daily life, then presented STEM products in detail based on the design process cycle, in order of how they acquired the knowledge, how they developed their ideas, how they built the prototype of their products, whether they tested and changed. Examples of products developed by students are given below—Table 4 is a complete list of STEM activities and the relationship between STEM disciplines.

3. RESULTS

3.1 The Effect of Design-Based STEM Activities on Perception

To decide the effect of the STEM integrated renewable energy sources course, paired sample t-test was used to analyze whe ther there were significant differences in renewable energy knowledge, relationship, renewable energy future vision, and the overall scale of renewable energy perception scale scores of students between the pre- and post-tests. While there were significant differences between the pre and post-tests scores for renewable energy knowledge ($t = 19.45, p \leq 0.05, d = 3.07$), renewable energy future vision ($t = 10.22, p \leq 0.05, d = 1.62$), renewable energy perception scale ($t = 9.93, p \leq 0.05, d = 1.57$), there were no significant differences between the pre-and post-test scores for relationship ($t = -0.77, p > 0.05, d = .12$) (Table 5). The effect size for renewable energy knowledge, renewable energy future vision, and renewable energy perception scale were large, according to Cohen (1988).

To decide the effect of the STEM integrated renewable energy sources course, the Wilcoxon test was used to analyze whether there were significant differences in renewable energy tendency scores of students between the pre-and post-tests. There were significant differences between the pre-and post-tests students' scores of renewable energy tendency ($z = -5.35, p \leq 0.05, r = .60$) (Table 6). The effect size for renewable energy tendency was large, according to Cohen (1988).

3.2 The Effect of Design-Based STEM Activities on Attitude

To decide the effect of the STEM integrated renewable energy sources course, paired sample t-test was used to analyze whether there were significant differences in the importance of education, country interest, environmental awareness and investments, and overall renewable energy sources attitude scale scores of students between the pre-

Table 7 Paired sample t-test results

Scale and subscales	N	$\bar{X}$	SD	DF	t	*p*	*d*
Post-test - Renewable energy sources attitude scale	40	3.74	.36	39	13.22	.00	2.09
Pre-test - Renewable energy sources attitude scale	40	2.26	.36				
Post-test - Importance of education	40	4.01	.48	39	13.28	.00	2.10
Pre-test - Importance of education	40	1.99	.48				
Posttest - Country interest	40	3.70	.74	39	5.93	.00	.94
Pre-test - Country interest	40	2.30	.74				
Posttest - Environmental awareness and investments	40	3.44	.53	39	5.15	.00	.81
Pretest - Environmental awareness and investments	40	2.57	.53				

Table 8 Wilcoxon test results

Pre-test application request – post-test application request	Negative Ranks	39	21.00	819.00	-5.51	.00	.62
	Positive Ranks	1	1.00	1.00			
	Ties	0					
	Total	40					

Table 9 Paired sample t-test results

Scale and subscale	N	$\bar{X}$	SD	DF	t	*p*	*d*
Post-test - Environment	40	3.85	.76	39	7.08	.00	1.12
Pre-test - Environment	40	2.15	.76				
Posttest - Sustainable consumption behavior scale	40	3.63	.53	39	7.49	.00	1.18
Pretest - Sustainable consumption behavior scale	40	2.37	.53				

and post-tests. There were significant differences between the pre and post-tests scores for importance of education (t = 13.28, $p \leq 0.05$, d = 2.10) country interest (t = 5.93, $p \leq 0.05$, d = .94), awareness (t = 5.15, $p \leq 0.05$, d = .81) and overall scores for renewable energy sources attitude scale (t = 13.22, $p \leq 0.05$, d = 2.09) (Table 7). The effect size for the importance of education, country interest, environmental awareness and investments, and renewable energy sources attitude scale was large, according to Cohen (1988).

To decide the effect of the STEM integrated renewable energy sources course, the Wilcoxon test was used to analyze whether there were significant differences in application request scores of students between the pre-and post-tests. There were signific ant differences between the pre-and post-tests students' scores of application request (z = -5.51, $p \leq 0.05$, r = .62) (Table 8). The effect size for application requests was large, according to Cohen (1988).

3.3 The Effect of Design-Based STEM Activities on Behavior

To decide the effect of the STEM integrated renewable energy sources course, paired sample t-test was used to analyze whether there were significant differences in environment and sustainable consumption behavior scale scores of students between the pre-and post-tests. There were significant differences between the pre and post-tests scores for environment (t = 7.08, $p \leq 0.05$, r = 1.12) and sustainable consumption behavior scale (t = 7.49, $p \leq 0.05$, r = 1.18) (Table 9). The effect size for the environment and sustainable consumption behavior scale was large, according to Cohen (1988).

To decide the effect of the STEM integrated renewable energy sources course, the Wilcoxon test was used to analyze whether there were significant differences in students' unneeded consumption, savings, and reusability scores between the pre-and post-tests. While there were significant differences between the pre-and post-tests students' scores of savings (z = -5.13, $p \leq 0.05$, r = .57) and reusability (z = -4.69, $p \leq 0.05$, r = .52), there were no significant differences between the pre-and post-tests students' scores of unneeded consumption (z = -1.14, p > 0.05, r = .13) (Table 10). The effect size for savings and reusability was large, according to Cohen (1988).

3.4 Examples of the STEM projects

In preparing STEM products, teacher candidates firstly took care of identifying the problem as a group and brainstorming about the predetermined problem in depth. Most of the groups considered the suggestions and ideas of the group members in the decision-making process. They had difficulties in processing science and engineering in the first activities. However, over time, they successfully integrated science and engineering in the stage of realizing the second and third designs. In terms of the design process, they used the design process effectively and carried out planning and testing. In terms of functionality, they designed functional products by paying attention to timing, but most chose to design similar products instead of original ones. Regarding the end product, teacher

Table 10 Wilcoxon test results

Subscales		N	Mean Rank	Sum of Ranks	*z*	*p*	*r*
Pre-test unneeded consumption - Posttest unneeded consumption	Negative Ranks	14	18.64	261.00	-1.14	.26	.13
	Positive Ranks	22	18.41	405.00			
	Ties	4					
	Total	40					
Pre-test savings – post-test savings	Negative Ranks	36	21.00	756.00	-5.13	.00	.57
	Positive Ranks	3	8.00	24.00			
	Ties	1					
	Total	40					
Pre-test reusability – post-test reusability	Negative Ranks	32	20.63	660.00	-4.69	.00	.52
	Positive Ranks	5	8.60	43.00			
	Ties	3					
	Total	40					

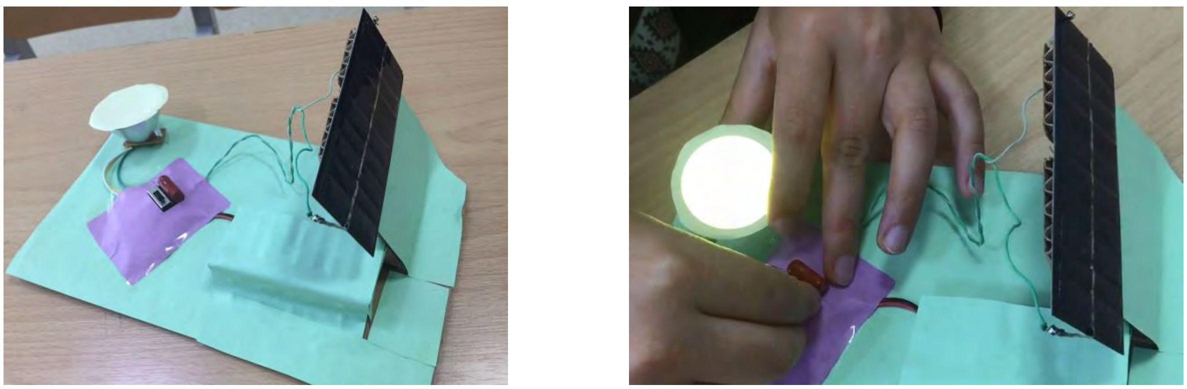

Figure 1 Solar-powered street lamp model

candidates designed solid products according to the plan by taking consistent measurements with suitable materials.

Sample photos and explanations of the designs were given below, respectively. Figure 1 showed the solar-powered street lamp model based on the environment and energy theme for street lighting. In this design, teacher candidates aimed to illuminate the street lamps by using electrical energy from solar energy. Teacher candidates realized an environmentally friendly street lighting project using renewable energy. For this design, teacher candidates used simple materials such as cardboard, glue, tape, small street lamp or LED lamps, solar panels, and scissors. At the end of this design, teacher candidates initiated in-class discussions and evaluations about the importance of designing a panel that receives sunlight all day, the orientation of the solar panel, the location where the design will be used in the world, and the efficiency of the lamp for their design. The STEM connections included electrical energy (science), measurement and calculations involving Ohm's Laws (mathematics), designing a street lamp model using an LED lamp and solar panel (engineering), and understanding the function and efficiency of the solar panel (technology).

Figure 2 illustrated the house model illuminated by wind energy in the context of using alternative wind energy to generate electricity. This design aimed to design a house with zero CO_2 emissions in terms of electrical energy. Electrical energy was generated sustainably by using renewable wind energy. In this design, teacher candidates used simple experimental materials such as small wind energy, wind turbines, toy car engines, wire, cardboard, cardboard tubes, LED lamps, and materials they could easily find in daily life. Before carrying out the design and preparing a plan, teacher candidates gathered information through deep research about the production process of electrical energy in wind farms and the mechanism of wind turbines. After that, teacher candidates mathematically analyzed the cost-effective and functional wind turbine prototypes to realize the model of the wind-lit house. They made frequent changes and rearrangements during the construction phase of the design. Finally, as a group, they completed a successful design process by giving the final shape to their designs and preparing their presentations. Teacher candidates consciously took care of the engineering design process during the design period. However, their designs were not very original models, although they were successful. The STEM connections included conservation of electrical and wind energy (science), measurement and calculations involving the law of the conservation of energy (mathematics), designing a house using renewable wind turbine (engineering), and

Figure 2 House model illuminated by wind energy

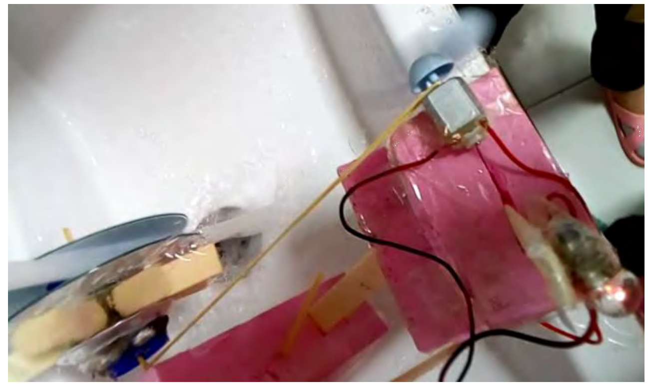

Figure 3 Water tribune model

understanding the function and mechanism of the wind tribune and micro-generation (technology).

Figure 3 demonstrated the water tribune model designed to generate electricity from accumulated rainwater. Teacher candidates developed a water tribune model to generate electrical energy that can be used for basic needs such as lighting by using the water that can be accumulated in nature and at high places such as the roof of houses. In this design, teacher candidates used recycling materials such as waste CDs and DVDs, waste jar lids, electric motors, wooden blocks, coin rubber, LED lamp, plastic boxes, ice cream sticks, and easy-to-find experiment materials. After determining the problem, teacher candidates gathered information by researching models similar to those they would make and the working mechanisms of hydroelectric power plants. Then, they created prototypes and realized their designs based on the information gathered. Although they made many changes while planning the prototype, they did not make any changes or adjustments by adhering to the plan during the design construction phase. This has led to a decrease in efficiency in their designs. At the design presentation stage, they stated that their design was limited by what aspects needed to reorganize. The STEM connections included the transformation of water energy to electrical energy (science), measurements and calculating the flow rate (mathematics), designing an efficient water turbine (engineering), and understanding the function and mechanism of the water tribune and micro-generation (technology).

4. DISCUSSION

The design-based STEM activities prepared for renewable energy sources positively affected teacher candidates' perceptions, attitudes, and behavioral orientations about renewable energy. Within this STEM integrated course, participants actively participated in the learning process (student-based) and made solutions and designs related to renewable energy for real-life problems. Thanks to this design-based learning, teacher candidates became independent learners and thinkers. Teacher candidates searched for solutions to the environmental problems they created based on their research, questioning, and design skills related to renewable energy sources from daily life. Design-based STEM activities positively improved the participants' perceptions, attitudes, and behavioral orientations towards renewable energy sources. In the literature, some studies reached similar results. In project-based activities, students' in-depth research to produce a product and their active participation in the process physically and mentally helped them understand renewable energy and the nature of STEM (Dallı, 2019). Students who successfully produce products can comprehend both the course content and the process successfully. In this study, teacher candidates' perceptions, attitudes, and behavioral orientations were improved after joining the design-based STEM activities about renewable energy sources. In the literature, students' perception, knowledge, and attitude variables towards the environment were increased with problem-based E-STEM activities (Amalya et al., 2021). As a result of this, the sense of responsibility and awareness of students improved, and their environmentally friendly behaviors improved thanks to E-STEM applications. Students' designing with STEM activities enabled students to learn about the environment and gain first-hand experience with renewable energy sources (Aguilar, Waliczek, & Zajicek, 2008). In addition, the activities contain more complex content, and too many disciplines have a more permanent positive effect on students' attitudes and behavioral orientations (Blackley & Sheffield, 2016). Teacher candidates were expected to think about how they can transfer what they have learned in the STEM-based courses and their professional development to their classrooms and develop an understanding of how to combine the content of other disciplines and integrate them into their lessons (Custer & Daugherty, 2009). Environmental-based STEM activities applied to students have been found to positively affect their views on STEM disciplines and environmental variables such as environmental awareness, attitudes, and environmentally friendly behaviors (Helvaci & Helvaci, 2019).

While an increase was observed in all sub-dimensions of the participants' perception after joining the design-based STEM activities about renewable energy resources, there was no statistically significant increase in the renewable energy-environment relationship sub-dimension of the renewable energy perception scale. This is because the items in the renewable energy-environment relationship sub-dimension are generally about the negative effects and cost of renewable energy facilities on the environment and living species such as humans, animals, and plants. Therefore, it can be deduced that the participants' field knowledge about the facilities and their perceptions about the importance of the facilities did not develop enough in this process (Liarakou et al., 2009). This situation derived from the skeptical thoughts of the participants about the facilities. In addition, although the perceptions of the science teacher candidates about renewable energy sources were at the desired level in the studies, they did not want to live in close areas because they did not have enough information about the negative impact on the environment in the power plants where this energy is produced (Cebesoy & Karışan, 2017). Similarly, in a study conducted with teachers, although teachers had sufficient knowledge and perception about renewable energy sources, they did not have enough perception of the renewable energy-environment relationship, so they felt inadequate to provide education on this subject (Halder, Havu-Nuutinen, Pietarinen, Zyadin, & Pelkonen, 2014). For this reason, designing and researching the renewable-environment relationship, as in this study, will positively affect their perceptions on this subject.

As the study's second research question, the effect of design-based STEM activities developed for renewable energy sources on the attitudes of science teacher candidates towards renewable energy sources was investigated. In this study, teacher candidates' attitude scores towards renewable energy sources increased statistically significant due to the application. Furthermore, after the application, it was found that the averages of the sub-dimensions of the attitude scale towards renewable energy sources were positive. This is in line with the findings of studies examining attitudes towards renewable energy sources (Bilen, Özel, & Driver, 2013; Çelikler & Kara, 2011; Genç, 2019; Yenice & Alpak Tunç, 2018; Zyadin et al., 2014). In these studies, the attitudes of teacher candidates (Bilen et al., 2013; Çelikler & Kara, 2011; Yenice & Alpak Tunç, 2018) and teachers (Liarakou et al., 2009; Zyadin et al., 2014) towards renewable energy sources were positive and thus supported the findings of this study. However, in the study conducted with science teacher candidates in the literature, teacher candidates' attitudes towards renewable energy sources did not change significantly after participating in design-based renewable energy activities (Uysal & Cebesoy, 2020). Furthermore, in the studies carried out with the science teacher candidates, the activities did not cause a significant change in the pre-service teachers' attitudes because the activities did not allow the students to gain experience, and the process was short. However, in the current study, the design-based STEM activities developed for renewable energy sources significantly changed their attitudes towards renewable energy sources since they provided the opportunity for science teacher candidates to design for renewable energy sources and covered 14 weeks.

There was an increase in all sub-dimensions of participants' sustainable behavior who participated in design-based STEM activities related to renewable energy sources, except for one sub-dimension of sustainable behavior. There was no significant difference in the unneeded consumption sub-dimension of sustainable behavior. The items in this sub-dimension aim to determine the participants' behavior towards buying new mobile phones, clothes, different products, and extra food, even though they are not needed. Due to their capitalist consumption habits, the participants tended to buy new and extra products, even if they did not need much. This study deduced that students' design-based STEM activities and unneeded consumption behaviors are difficult to change because they have long-term behavioral habits. In design-based STEM activities, the attitudes and behaviors of the participants towards the environment can also be determined by the products they present. Candan-Helvaci (2021) stated that integrating the environmental dimension into the STEM approach can be achieved by adding the environmental dimension to the engineering design process. The engineering design process starts with selecting an environmental problem, and then environmental awareness and literacy impact determining this problem. In this case, the participants are expected to change their environmental attitudes and perceptions. Individuals can develop pro-environmental behaviors while pro-environmental product prototypes are being created. In the last step, it is possible to examine whether individuals have pro-environmental behaviors, environmental literacy levels, and pro-environmental awareness while presenting a pro-environmental product. Environmental education aims to develop awareness, attitude, and, most importantly, pro-environmental behavior towards the environment. Since the practice-oriented structure of the STEM approach matches up with the pro-environmental behavior purpose of environmental education, the goals in environmental education turn into action through STEM activities.

In the studies conducted, science teacher candidates generally have difficulties in creating a problem for a design for the first time and doing research about the problem. For example, Bozkurt Altan, Yamak, and Buluş Kırıkkaya (2016) observed science teacher candidates through certain problem situations. Furthermore, teacher candidates were asked to design their STEM-supported learning environments and implement them in the classroom. In the study conducted with six teacher candidates in the Science Teaching Laboratory course, teacher candidates had difficulties determining the problem situation, finding the most appropriate solution, and designing a product. Time is the factor that teacher candidates and undergraduate students have the most difficulty in creating a STEM-based learning environment and performing design activities (Delen & Uzun, 2018).

Another significant result was that some of the science teacher candidates had difficulties processing and integrating science and engineering. The difficulties in processing science and engineering on a design and integrating it into a design were expected when it was considered that some science teacher candidates might have their first practical experience. It is a complex process to prepare a design by integrating the fields that have been considered separately for many years within the scope of STEM education (Sanders, 2009). Although science, mathematics, technology, and engineering are separate disciplines, STEM education focuses on their interconnection (Krajcik & Delen, 2017). Sanders (2009) allows students to demonstrate their knowledge and skills in mathematics and science in the problem-solving process by having students make purposeful designs and questioning. This study tried to provide sufficient time and environment for students to identify their problems and realize their designs for this problem. In this way, although the students initially had difficulties using science and engineering, they could develop these aspects in time and the problem-solving environment. Unfortunately, designing STEM products with teachers and students is very difficult, and the participants are not successful in integrating STEM fields (Bozkurt Altan et al., 2016).

One of the significant results was that science teacher candidates could not produce innovative and original products using their creativity and imagination, which is frequently encountered during the realization of STEM products and designs. Most teacher candidates followed the engineering design process closely and were influenced by the models and designs in the literature. However, the pre-existing designs in the literature prevented them from developing their designs. Furthermore, students were accustomed to following a particular order even in problem-solving processes, especially laboratory applications, limiting their creativity (Ayar, 2015). Similarly, mathematics teacher candidates' tendency to create designs that were previously designed according to specific rules, even in creating a STEM design environment, to use limited their imagination and creativity (Delen & Uzun, 2018). The reason for this was related to the teacher candidates' misconceptions about integrating engineering into the STEM design process.

CONCLUSION

The design-based STEM education about renewable energy sources helps students think critically about the environment, the effects of humans on the environment, and their interest in science careers (Gupta, LaMarca, Rank, & Flinner, 2018). It is also well recognized that applied environmental initiatives help science concepts last longer (Dieser & Bogner, 2016). While environmental education contributes to the success of the STEM method, it can also provide new avenues for environmental education (Fraser, Gupta, Flinner, Rank & Ardalan, 2013; Kuvaç & Koç-Sari, 2018). It is a topic that has been investigated using the Environmental E-STEM approach, and its framework is currently being developed (North American Association for Environmental Education [NAAEE], 2013). Nature Works Everywhere (NWE) is a research-based example program that involves the use of the environment in science, technology, engineering, and mathematics teaching as well as additional materials for a nature-centered science curriculum (National Wildlife Federation [NWF], 2015).

In order to construct STEM designs effectively, teacher candidates can participate in more application-oriented activities, take care of timing and creativity in their designs, and experience in incorporating technology and engineering into this process rather than establishing interdisciplinary relationships. Teacher candidates were expected to create original designs using STEM disciplines' knowledge, skills, and creativity (Krajcik & Delen, 2017). As a result, developing the field-specific knowledge and skills of teacher candidates, designing based studies including different disciplines, evaluating STEM products and performances in different sample groups, and training STEM teachers instead of field-specific teachers were recommended based on research results. Implementing STEM in other courses and integrating it with other disciplines will help students better understand the nature of STEM and design effective STEM products.

The most critical responsibility for gaining perceptions, attitudes, and behaviors towards renewable energy in future generations belongs to the science courses in which these subjects take place and the science teachers who are the instructors of these courses. For this reason, the increase in science teacher candidates' perceptions, attitudes, and behaviors about renewable energy sources will be reflected in their classroom teaching practices. Only in this way can future generations be raised consciously on these issues. With this study, science teacher candidates studying in a province rich in renewable energy sources were provided to make STEM-based designs for these energy sources. In addition, the effect of design-based STEM activities about renewable energy sources on the perceptions, attitudes, and behaviors of science teacher candidates about renewable energy was revealed.

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