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The Effect of STEM Activities on Pre-Service Elementary Teachers' Academic Achievement*

Ezgi Akkuş[1], Nilüfer Okur Akçay[2]

[1] *Graduate Student, Ağrı İbrahim Çeçen University, ezgiakkus16@gmail.com, ORCID ID: 0000-0001-6835-6394*

[2] *Prof. Dr., Ağrı İbrahim Çeçen University, Education Faculty, nilokur-7@hotmail.com, ORCID ID:0000-0002-3276-5564*

This study prepared from master thesis of the first author.

ABSTRACT

The aim of this research is to determine the effect of STEM activities in the Science and Technology Laboratory Practices-II course on pre-service elementary teachers' academic achievement and the permanence of their knowledge. The sample of the research consists of 63 pre-service elementary teachers studying in the first and second groups of the second year of Educational Faculty in the 2018-2019 academic years. While the first group of these groups was taught according to the STEM education approach (n=30), the second group was randomly determined according to the deductive laboratory approach (n=33). This research is in the quasi-experimental design model with pretest-posttest experimental group, which is one of the quantitative research approaches. Academic achievement test was used in the research. SPSS program was used for data analysis. According to the research findings, it is seen that the STEM education approach increases academic achievement and provides permanence compared to the deductive laboratory approach. As a result of the research, some suggestions were made.

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STEM Etkinliklerinin Sınıf Öğretmeni Adaylarının Akademik Başarılarına Etkisi

ÖZ

Bu araştırmanın amacı, Fen ve Teknoloji Laboratuvar Uygulamaları-II dersinde STEM etkinliklerinin sınıf öğretmeni adaylarının akademik başarılarına ve bilgilerinin kalıcılığına etkisini belirlemektir. Araştırmanın örneklemini 2018-2019 eğitim öğretim yılında Eğitim Fakültesi 2. sınıfın birinci ve ikinci gruplarında öğrenim gören 63 sınıf öğretmeni adayı oluşturmaktadır. Deney grubunda yer alan sınıf öğretmeni adayları STEM eğitimi yaklaşımına göre (n=30) eğitim görürken, kontrol grubunda yer alan sınıf öğretmeni adayları ise tümdengelimli laboratuvar yaklaşımına göre (n=33) eğitim görmüşlerdir. Gruplar rastgele seçilerek belirlenmiştir. Bu araştırma nicel araştırma yaklaşımlarından biri olan ön test-son test kontrol gruplu yarı deneysel tasarım modelindedir. Araştırmada akademik başarı testi kullanılmıştır. Veri analizinde SPSS programı kullanılmıştır. Araştırma bulgularına göre STEM eğitimi yaklaşımının tümdengelimli laboratuvar yaklaşımına göre akademik başarıyı artırdığı ve kalıcılık sağladığı görülmektedir. Araştırma sonucunda bazı önerilerde bulunulmuştur.

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ANAHTAR KELİMELER: STEM, STEM modülleri, Akademik başarı, Sınıf öğretmeni adayı.

Introduction

With the globalization in the world, social, economic, political etc. various changes and developments occur in various fields. This is also experienced in science and technology. This change is used of different ways other than using ready-made information. Unlike using ready-made knowledge, taking a role in solving an existing problem and reaching a conclusion by using the steps of scientific research takes the individual away from classic learning (Hiğde and Aktamış, 2017; King and English, 2016).

In the 21st century countries to compete globally, individuals must have some characteristics. The ability of countries to compete globally in the 21st century depends on having individuals who research, question, have problem-solving skills, are curious, creative, analytical thinking, transfer what they have learned to their lives, innovate, and productive (Ernst and Haynie, 2010; Fan and Yu, 2017; Suratno et al., 2020). For the development of these characteristics in individuals, the education approach which used should be appropriate for the age. As it is known, with the 21st century, new educational approaches have emerged that attract the attention of all countries in the world. One of these educational approaches is the STEM education approach. The STEM education approach consists of the integration of four different fields. It has duties in integration in these four different areas. Engineering and technology fields, where theoretical knowledge in the fields of science and mathematics are transformed into practice, offer different solutions to the problems of individuals (National Academy of Engineering [NAE] and National Research Council [NRC], 2009). STEM (Science, Technology, Engineering, and Mathematics) education is the application of disciplinary knowledge and skills together with an interdisciplinary approach to solving real-world problems (Akarsu, Okur Akçay and Elmas, 2020). For this reason, applications based on STEM education help individuals to solve problems by offering various solutions to individuals with technology and engineering disciplines. As it is known, the importance of STEM activities has increased even more due to the fact that active and cooperative learning method is more effective in terms of providing the gains and that STEM activities produce original products with active participation due to the collaborative work of the students (Can and Uluçınar-Sağır, 2018). According to Honey et al. (2014), teachers who teach the STEM education approach to their students play an important role in providing their students with positive learning and orientation towards STEM education.

For STEM education to be more qualified, teachers should be trained in these areas and teachers should have the necessary competence (Peterman et al., 2017; Wang, 2012). For this reason, it is important to train teachers who can carry out STEM education (Hacıömeroğlu, 2018). One of these teaching fields is the classroom education program. Classroom education program includes elementary school education. Since elementary school is a stage where basic knowledge and skills are acquired, the knowledge and skills gained at this stage contain the information necessary for higher learning. STEM education also important in this period. Although the explanations made by Conderman and Woods (2008) and DeJarnette (2012) were made at the secondary school level, it was stated that the elementary school level is a critical period for students to develop their interest in STEM (Zengin and Uğraş, 2019).

Advances in science and technology necessitated changes in education programs also. In this context, necessary changes were made in the curriculum in Türkiye and with the last change made in 2018, STEM education was emphasized in the program. However, how to use STEM education in schools is a complex issue (English, 2017). In addition, while it is an important situation to meet the costs while applying the STEM education approach, it is an important situation in our country how the funds allocated in public schools can be included in the process with the STEM education approach (Elmas and Gül, 2020). In addition to this, the fact that teachers, who are the implementers of education, have problems in applying the STEM education approach in their classrooms can be considered as another possible complication.

Studies on STEM education have positive effects on students and pre-service teachers' scientific process skills development, their attitudes towards STEM, the permanence of knowledge, the development of 21st century skills, whether it is an effective method, increasing attitude and motivation, increasing academic success, and improving problem-solving skills (Altaş, 2018; Biçer, 2019; Moore et al., 2013). In the literature, there are studies on STEM education with pre-service elementary teachers. In these studies, especially focused on scale development, taking the opinions of pre-service teachers towards STEM and determining their attitudes towards STEM (Altaş, 2018; Anagün et al., 2020; Hacıömeroğlu and Bulut, 2016; Kırılmazkaya, 2017; Şahiner, 2020). Another study conducted is engineering design-based STEM studies with pre-service elementary teachers (Altaş, 2018; Şahiner, 2020). However, in the studies conducted, a module study developed on the basis of engineering design in the "Science and Technology Laboratory II" course with pre-service elementary teachers was not encountered. The purpose and importance of the laboratory in science teaching; safety in the laboratory; scientific method, scientific process skills and how they are acquired; laboratory experiments for elementary school (planning, conducting and evaluating the results of the experiments), test worksheets and preparation of the experiment report; examples of experiments that can be made with simple and inexpensive materials; group studies. We were interested in researching how pre-service elementary teachers applied science, mathematics and technology concepts when given an electrical engineering problem to solve using an iterative engineering design model. An important aspect of learning to teach engineering design is the discrete type of information that teachers, especially conceptual knowledge of the engineering design process, should acquire. In other words, teachers should know what the engineering design process involves and how engineers describe it. The benefits of engineering education in elementary education are as follows (Katehi, Pearson, and Feder, 2009):

- Increasing meaningful learning in science and mathematics,
- Increasing awareness of engineering,
- Increasing the ability of engineering design,
- Being aware of engineering skills and heading towards this field,
- Increasing technology literacy.

Engineering-based solutions are created for real-life problems in learning environments suitable for the STEM education approach. Based on the solution of problems, students highlight their reasoning skills by providing collaborative and communicative discussion (Okur Akçay, 2020). As such, we adopted the engineering design model (Moore et al., 2013) and used it to structure the activity. The engineering design model involves a series of steps that guide engineering teams as they solve problems. The series of steps in the engineering design model processes as: define, learn, plan, try, test, and decide. In this study, we use engineering design process as a context for developing science, mathematics and technology concepts. Unlike other pedagogical approaches in STEM education, engineering and design come to the fore with this engineering design model (Akarsu, Okur Akçay and Elmas, 2020). In this direction, the aim of this research is to determine the effect of the STEM activities in the Science and Technology Laboratory Practices-II course on the pre-service elementary teachers' academic achievement and the permanence of their knowledge. The problem statement of the research is "Do the applications prepared in accordance with the STEM education approach have an effect on the academic success and permanence of knowledge of pre-service elementary teachers?". The sub-problems of this study prepared in this direction are as follows:

1. Is there a significant difference between the scores of the experimental and control groups from the AAT pre-test?

2. Is there a significant difference between the scores of the experimental and control groups from the AAT post-test?
3. Is there a significant difference between the average scores of the permanence test of the experimental and control groups?

Method

This research is in the quasi-experimental design model with pretest - posttest experimental and control group, which is one of the quantitative research approaches. In many schools or classrooms, it is appropriate to apply a quasi-experimental research design to determine the effect of teaching materials or teaching methods (McMillan and Schumacher, 2010). The quasi-experimental design is used when the sample selection for the control and experimental groups is not made randomly (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz and Demirel, 2012). Since the branches of the students in the sample group were determined beforehand, no random assignment was made in this study. For this purpose, the experimental and control groups were determined randomly.

Sample of the Research

The sample of the research consists of a total of 63 pre-service elementary teachers studying in two different affiliate of the second year of the Faculty of Education, Department of Elementary Education in the spring semester of the 2018-2019 academic year. One of these affiliates was determined as the Experimental Group (EG=30) in which the STEM education approach was applied, and the other as the Control Group (CG=33) in which the deductive laboratory approach was applied.

Data Collection Tool

As a data collection tool in this research Academic Achievement Test (AAT) was used. In addition, the academic achievement test was applied again as a permanence test in order to determine the permanence of the knowledge of the experimental and control groups. The data collection tool is described below.

The Academic Achievement Test (AAT) was formed in accordance with the modules that includes some subjects. These subjects are; electricity, magnets, electromagnets, shadow formation and mirrors. Initially, the pilot study of the AAT, which consisted of 35 questions, was applied to a total of 103 pre-school elementary teachers in the 3rd and 4th grades of Faculty of Education, Department of Elementary Education. As a result of the pilot study, the KR-20 reliability coefficient of the AAT was determined as 0.71, and the item difficulty and item discrimination index values of the questions are given in the table below.

Table 1.

Item Difficulty and Item Discrimination Index Values of the Questions in the AAT

Q-No	Item Difficulty Index	Item Discrimination Index	Q-No	Item Difficulty Index	Item Discrimination Index
1	,08	,16	**19**	,08	,09
2	,18	-,09	**20**	,12	,29
3	,18	,29	**21**	,21	,26

4	,10	0	**22**	,21	,29
5	,02	,03	**23**	,13	,19
6	,32	,59	**24**	,16	,39
7	,25	,42	**25**	,13	,32
8	,10	,26	**26**	,20	,39
9	,04	,06	**27**	,22	,29
10	,19	,22	**28**	,17	,19
11	,31	,42	**29**	,12	,19
12	,08	0	**30**	,16	,26
13	,13	,09	**31**	,13	,22
14	18	,39	**32**	,11	,26
15	,19	,36	**33**	,13	,19
16	,11	,16	**34**	,24	,29
17	,30	,59	**35**	,15	,29
18	,09	-,06			

The items in Table 1 were evaluated by experts in the field in line with the information below.

0.40 and greater: An item with very good discrimination, can be used.

0.30-0.39: It needs to be improved.

0.20- 0.29: It should be fixed and improved.

0.19 and less: Very weak substances. If it cannot be corrected, it should be removed from the test (Tekin, 2003).

The information given above, items 1, 2, 4, 5, 9, 12, 13, 16, 18 and 19 were excluded from the test according to Table 1. These 10 removed items did not affect the content validity of the test. The KR-20 reliability coefficient of the AAT, which was reduced to 25 questions, was recalculated and found to be 0.81. AAT was applied as pre-test, post-test and permanence test.

Implementation Process

This research was carried out in the Science and Technology Laboratory Practices-II course of pre-service elementary teachers. In the experimental and control groups, the activity processes lasted for a semester. The activities were carried out by the researcher and the lecturer of the course. The selection of the subject of the course, the implementation process of the experimental and control groups are given below.

Subject Selection

While choosing the subject, first of all, the 3rd and 4th grade curriculums, in which the elementary teachers conduct the science lesson, were imposed on. In this direction, the subject selection was carried out considering the unit achievements in the Science Curriculum of the Ministry of National Education (MoNE). Units benefiting from the achievements of the “Science Curriculum”; at the 3rd grade level the "Light Sources" subject under the "Light and Sounds Around Us" unit and the "Electric Vehicles" unit, and the 4th grade level; the subject of "Force Applied by Magnets" under the title of "Effects of Force" consists of "Lighting and Sound Technologies" unit and "Simple Electrical Circuits" unit. Considering the units and achievements in the program, the course content that is planned to be applied to pre-service elementary teachers has been formed.

Implementation Process in the Experimental Group

After the subject selection phase was completed, it was ensured that the modules were formed in accordance with the STEM education approach. This phase lasted about 2 months. Care was taken to ensure that each module was at the level of pre-service elementary teachers. Detailed information about the modules and the learning outcomes related to the discipline areas on which they are based are given in the Table 2 below.

Before starting the implementation process, AAT was applied to the pre-service elementary teachers as a pre-test. Then, the course implementation process was started. In the experimental group, the courses were conducted in accordance with the STEM education approach, based on engineering design. Before starting the lesson, necessary information was given to the pre-service elementary teachers, and it was ensured that the pre-service elementary teachers were ready for the activities within the scope of the plan.

The implementation process carried out in the steps of the engineering design process followed in the acitivity process; Adjustable switch design, long-lasting working doll design, device design that can attract metals, design of creating space in different lighting and room design modules with mirrors were applied. In this study, the engineering design process (EDP) steps developed by Moore et al. (2013) were used. MTS consists of six steps. These steps are:

Defining: The first stage in the engineering design process is defining the problem. In this step, the scenario situation given in accordance with the real life problem is read. Depending on this scenario, the problem is defined. When creating scenarios, the desired results should be stated clearly and explicitly, and criteria and restrictions should also be included. At this stage, it is very important for students to define the problem correctly. At this stage, the concepts of criteria and restrictions are key concepts in creating the product. It is important that the equivalents of these concepts are easily extracted and understood by the prospective teachers in the scenario. Otherwise, errors may occur in creating the desired product. This may cause the process to start over and cause loss of time.

Learning: The learning step, which is the second step of the engineering design process, is the step in which individuals acquire the preliminary learning necessary to create their designs. It is important at this point that the student learns information that will be useful in design. For this reason, the teacher must plan the information for the student's learning very well. Learning is not given directly by the teacher.

Planning-Trying: In the planning stage, students draw individual design plans for solving the problem. Then they express their thoughts to support this design. At this stage, it is essential to develop a design plan that includes processes such as brainstorming and developing multiple solutions. Students decide on a common design plan with their group mates. It is important for them to brainstorm and discuss with their group mates when making a decision. In addition, the teacher should examine the plan drawings in each group at this stage and question the students about what this plan is for and why they drew this plan.

Testing-Decision Making: Testing and decision-making in the design process is based on the principle that students evaluate the product or solution by collecting and analyzing data, determine its strengths and weaknesses, and use these steps to improve the product. At this stage, students test the design idea they determined in the planning and testing phase. While testing the design, they note the information, graphics and drawings they obtained about the design in their engineering notebooks. During the testing phase, attention should be paid to whether there is a design that will meet the problem situation, taking into account the criteria and restrictions along with the problem situation.

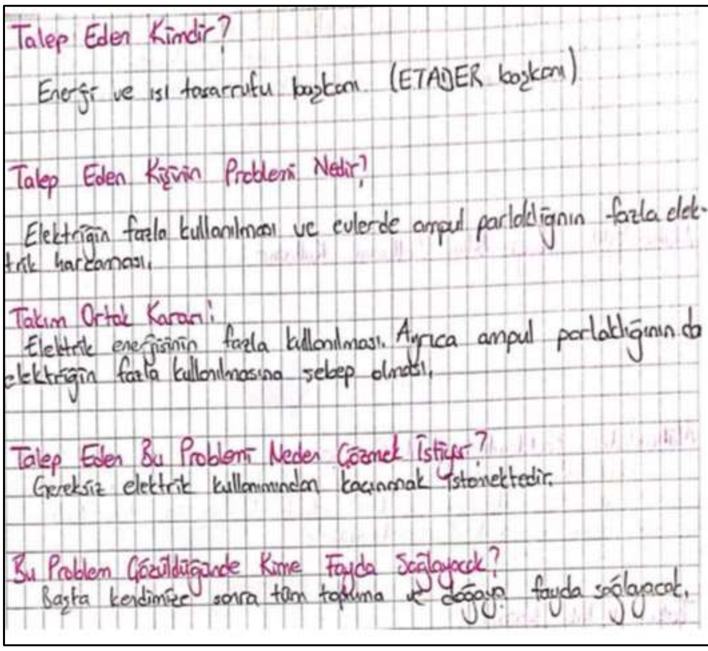
Table 2. *Learning Outcomes for Discipline Fields*

Modules	Experiments	Science	Technology	Engineering	Mathematics
1. Adjustable switch design (7 lesson time)	1. Simple electrical circuit 2. Resistor	Can set up a simple electrical circuit. -Knows how resistance has an effect on the electrical circuit. -Understands the relationship between the length and cross-sectional area of the wire and the brightness of the bulb	Knows that all the materials they use are technological products. -Knows that the product he will create is a technological product that makes life easier.	He knows what the problem is like an engineer.--Knows the science and mathematics connections necessary to create the product like an engineer. -Makes plans and drawings of the product to be created like an engineer.	-Analyzes data -Knows how to draw graphics. -Knows that there is an inverse proportion between the data as one increases and the other decreases. -He knows that as one of the data increases, the other increases, and there is a direct proportion between them.
2. Long-lasting working doll design (5 lesson time)	1.Circuits connected in series 2. Circuits connected in parallel	-Can create series and parallel circuits. -In a series connected battery circuit, it tells that the bulb will not light when a battery is disconnected. -Knows that the brightness of the bulb will not change as the number of batteries increases in a parallel battery circuit.	-Knows that all the materials they use are technological products. -Knows that the product he will create is a technological product that makes life easier.	He knows what the problem is like an engineer. -Knows the science and mathematics connections necessary to create the product like an engineer. -Makes plans and drawings of the product to be created like an engineer.	-Analyzes the data. -Knows how to draw graphics. -He knows that as one of the data increases, the other increases, and there is a direct proportion between them. -Compares battery depletion times in circuits.
3. Capable of attracting metals device design (5 lesson time)	1. Magnet and its properties 2. Electromagnet	-Knows that all magnets are bipolar. -Different types of magnets are not related to the magnitude of the attraction force. He discovers by experimenting and says that the gravitational force depends on the material that makes up the magnet. -Knows that a non-magnetic metal can be temporarily magnetized.	Knows that all the materials they use are technological products. -Knows that the product he will create is a technological product that makes life easier.	- He knows what the problem is like an engineer. Knows the science and mathematics connections necessary to create the product like an engineer. -Makes plans and drawings of the product to be created like an engineer.	-Analyzes the data. -Knows how to draw graphics. -He knows that as one of the data increases, the other increases, and there is a direct proportion between them. -Uses obstacles of different sizes.
4. In Different Brightness Design of Space Creation (5 lesson time)	1. Classification of Transparent, Translucent and Non-Transparent Materials 2. Shadow	-Knows that light cannot pass through all matter. -Classifies the surrounding objects as transparent matter, translucent matter and non-transparent matter. -Experiment and observe the variables that affect the full shadow and penumbra.	-Knows that all the materials they use are technological products. -Knows that the product he will create is a technological product that makes life easier.	- He knows what the problem is like an engineer. -Knows the science and mathematics connections necessary to create the product like an engineer. -Makes plans and drawings of the product to be created like an engineer.	-Analyzes the data. -Knows that there is an inverse proportion between the data as one increases and the other decreases. -Compares full shadow and penumbra areas by using the light source and the screen at different distances.
5. Illuminated with Mirrors Room Design (6 lesson time)	1. Reflection in the Plane Mirror 2. Reflection in Concave Mirror and Convex Mirror	-Tells what mirror types are and distinguishes mirrors. -Can make observations and drawings by trying the special rays in the pit mirror. -Knows that the images in the mirrors are different from each other.	-Knows that all the materials they use are technological products. -Knows that the product he will create is a technological product that makes life easier.	- He knows what the problem is like an engineer. -Knows the science and mathematics connections necessary to create the product like an engineer. -Makes plans and drawings of the product to be created like an engineer.	-Analyzes the data. -He knows that as one of the data increases, the other increases, and there is a direct proportion between them. -Learns by experimenting with special rays in the concave mirror using laser light.

Below are examples made by pre-service elementary teachers during the implementation process of the adjustable switch design modüle in the field of the **defining phase.** When the examples of the Engineering Design Notebook (EDN), one of the pre-service elementary teachers are examined during the implementation process, the questions answered by the pre-service elementary teachers after reading the scenario in the notebook are given below.

Figure 1

Questions Answered After Reading The Script



-Who is the requester?
Head of energy and heat saving (ETADER)

-What is the requester's problem?
Excessive use of electricity and excessive consumption of light bulbs in homes

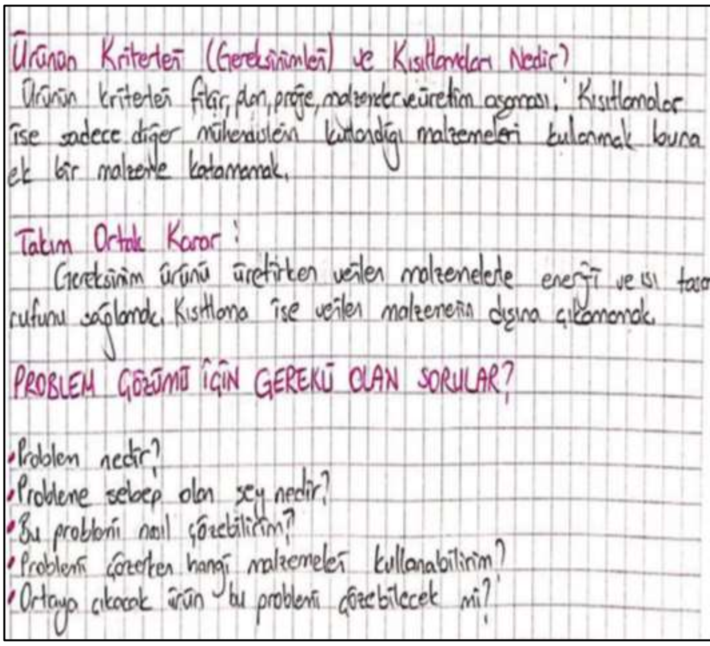
-Team Joint Decision:
Excessive use of electrical energy. In addition, the brightness of the bulb causes excessive use of electricity.

-Why does the requester want to solve this problem?
It wants to avoid unnecessary electricity use.

-Who will benefit when this problem is solved?
It will benefit firstly ourselves, then the whole society and nature.

Figure 2

Determining the Criteria and Constraints of the Scenario



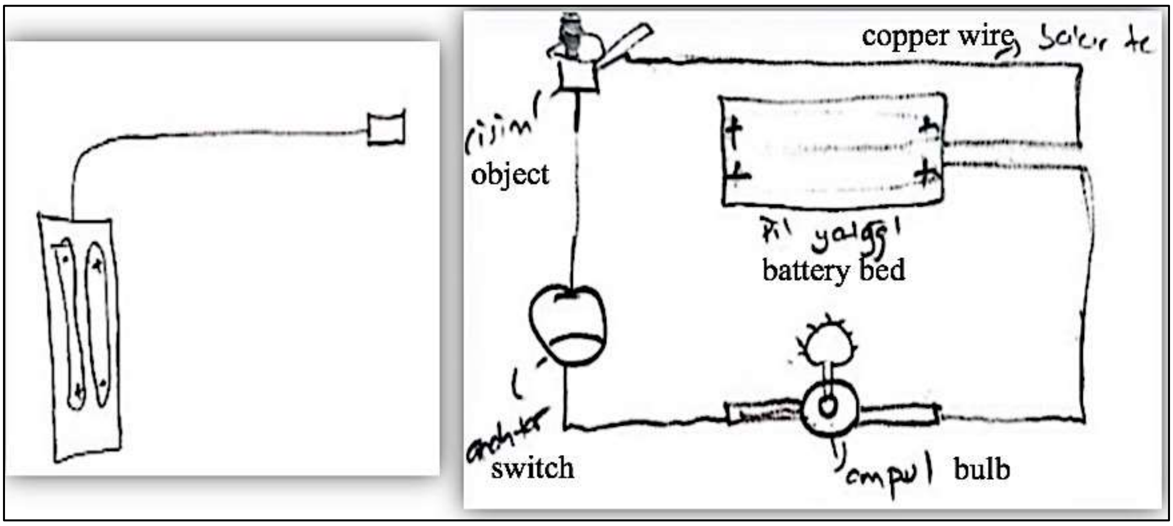
-What are the Criteria (requirements) and Restrictions of the Product?
The criteria of the product are idea, plan, project, materials and production stage. The constraints are to use only materials used by other engineers and not be able to add materials to it.
-Team Joint Decision:
The criterion is to save energy and heat with the materials given while revealing the product. The limitation is not being able to go beyond the given material.
-Questions Required for Problem Solving
What is the problem?
What is causing the problem?
How can I solve this problem?
What materials can I use to solve the problem?
Will the resulting product solve this problem?

After the definition of the problem in the implementation process, the pre-service elementary teachers who pass to the learning stage of engineering design process gain experiences where they can write their preliminary knowledge information and obtain the necessary information for the design after the experiments.

In the figure below, pre-service elementary teachers were asked to draw the simple electric circuit and then draw the simple electric circuit again as a result of their experiences.

Figure 3

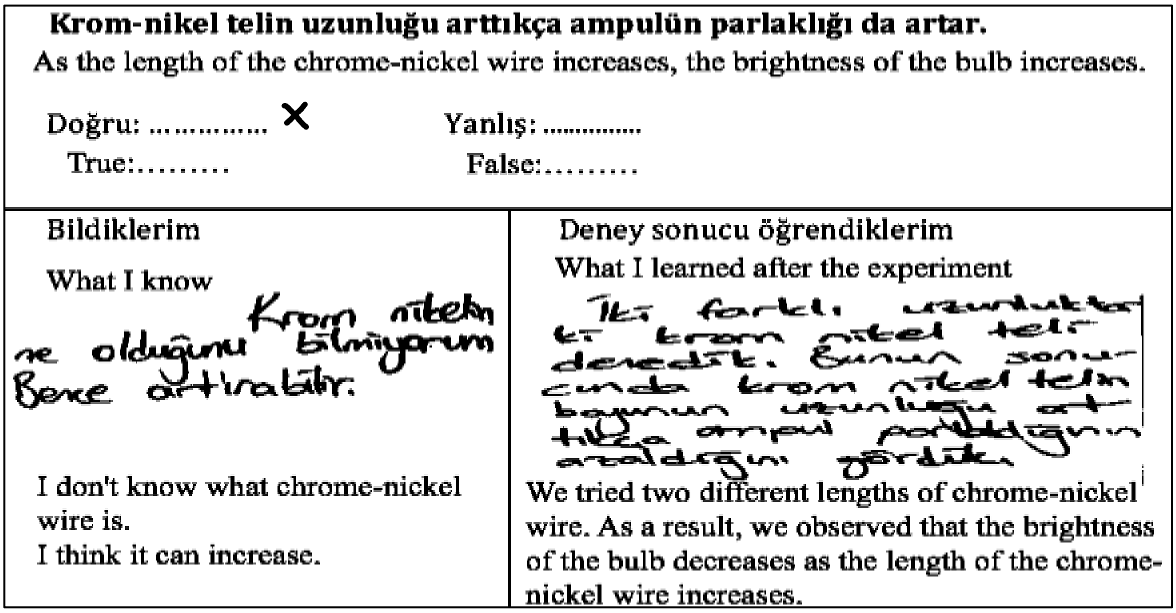
Example of Preliminary Drawing (Left) and Post-Trial Drawing (Right)



Examples of areas where teacher candidates can also write their previous knowledge in the field of the **learning phase** and the knowledge they have learned after the experiments are given below.

Figure 4

An Example of a Question in the Learning



Krom-nikel telin uzunluğu arttıkça ampulün parlaklığı da artar.
As the length of the chrome-nickel wire increases, the brightness of the bulb increases.

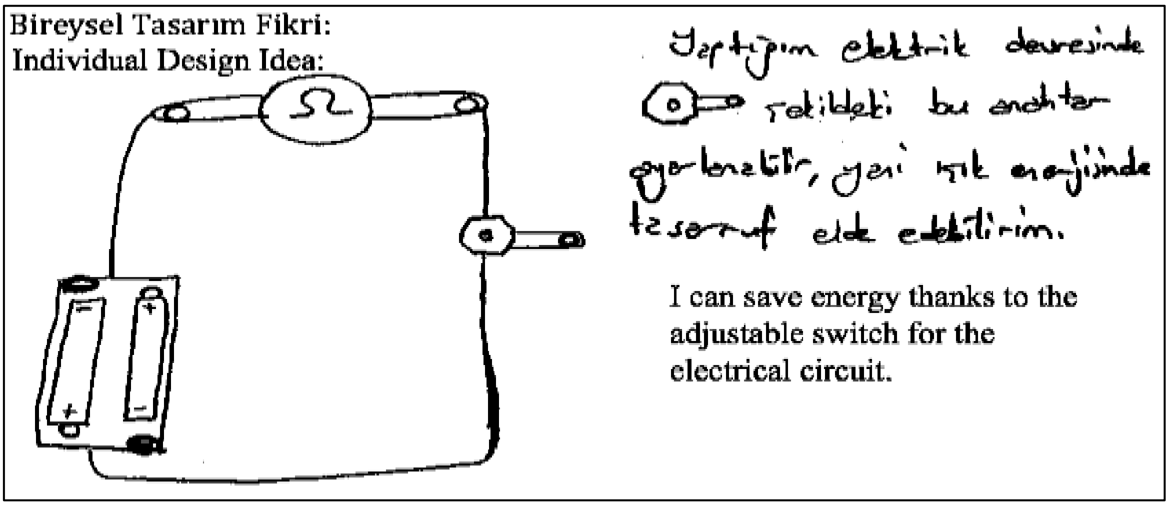
Doğru: .... ✕ Yanlış: ....
True:......... False:.........

Bildiklerim What I know	Deney sonucu öğrendiklerim What I learned after the experiment
Krom nikelin ne olduğunu bilmiyorum Bence artırabilir. I don't know what chrome-nickel wire is. I think it can increase.	İki farklı uzunlukta krom nikel teli denedik. Bunun sonucunda krom nikel telin boyunun uzunluğu arttıkça ampul parlaklığının azaldığını gördük. We tried two different lengths of chrome-nickel wire. As a result, we observed that the brightness of the bulb decreases as the length of the chrome-nickel wire increases.

The practices in which pre-service elementary teachers draw their individual plans during **the planning and trying phase**, what they do, then draw their joint plans as a group, and what their designs are useful for, are given below in EDN.

Figure 5

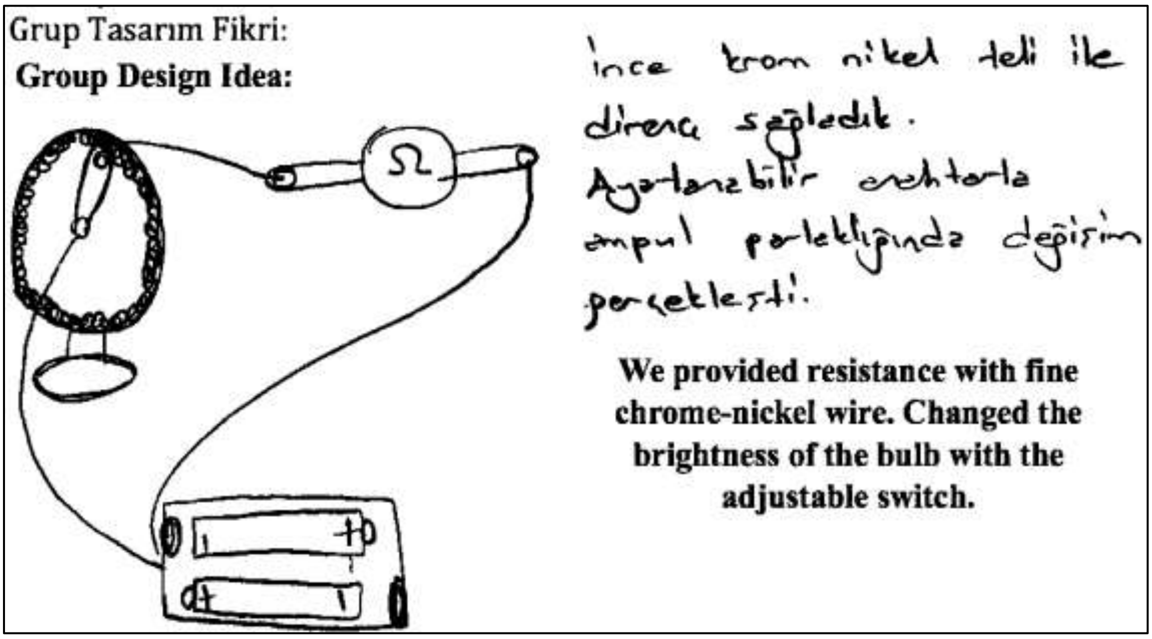
An Example of an Individual Design Drawing



Pre-service elementary teachers who make their individual designs examine the drawings of each design as a group and have a common design idea. An example is given below.

Figure 6

An Example of Group Design Drawing



After the pre-service elementary teachers have determined the drawings of the design they will make as a group, the properties of the materials they use in the design they have decided on, how these materials affect the design, and how they support the criteria and restrictions in **the testing-decision making phase** are given below.

Figure 7

An Example of the Materials Used and Their Effect on the Design

Kullanılan malzemeler ve bu malzemelerin tasarımdaki etkisine yönelik grup fikrinizi yazınız.

Write your group idea about the materials used and the effect of these materials on the design.

İnce krom nikel ile direnç sağladık
Ayarlanabilir anahtar ile direnci kontrol altına aldık.
İnce tel ile ampul parlaklığı azalttık

We provided resistance with fine chrome-nickel.
We took the resistance under control with the adjustable wrench.
We reduced the bulb brightness with thin wire

Figure 8

An Example of Data Supporting Criteria and Constraints

Bu tasarımdaki kriter ve kısıtlamalarınızı destekleyen verileriniz nelerdir?

What are your data supporting about your criteria and constraints in this design?

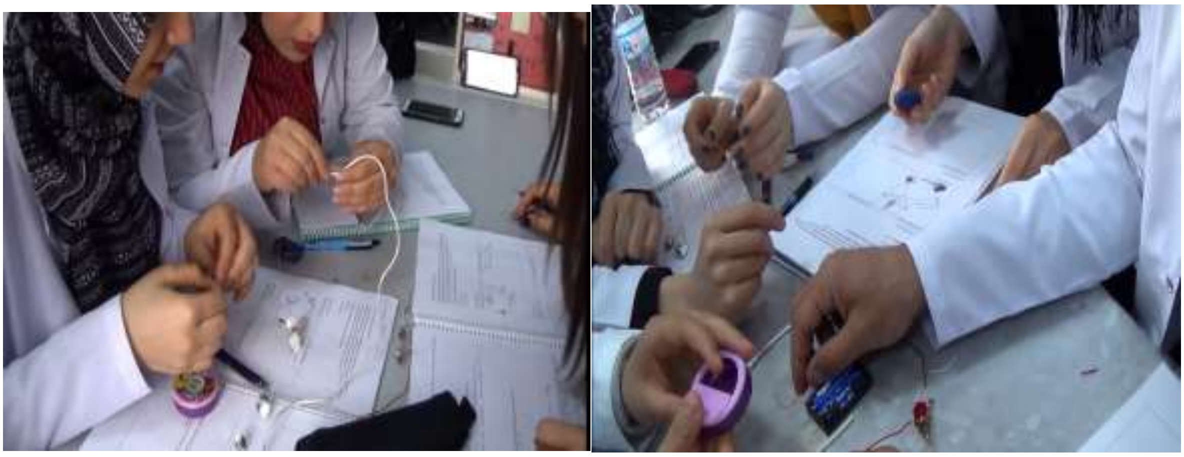
Kullandığımız telin kalınlığı ve inceliği ile ampule direnç sağladık. Bu direnci anahtar ile bağladık. Bu da ampulün parlaklığında azaltma ya da arttırma sağlayarak ulaşmak istediğimiz tasarruf fikrine daha çok yaklaşmış olduk.

We provided resistance to the bulb with the thickness and thinness of the wire we used. We connected this resistor with the switch. This brought us closer to the saving idea we wanted to achieve by decreasing or increasing the brightness of the bulb.

The pre-service elementary teachers realized their designs at the end of the implementation on process. There are designs made by the pre-service elementary teachers for each module as a group. Pre-service elementary teachers prepared posters as a group at the end of each module. The pre-service elementary teachers 'work is given in Figure 9 below.

Figure 9

Pre-Service Elementary Teachers' Work



After the implementation process, AAT was applied again as a post-test. In order to determine the permanence of the information, AAT was applied to the teacher candidates as a permanence test 4 weeks later and the process was completed.

Implementation Process in the Control Group

The experiments planned to be implemented in the control group were determined in parallel with the modules developed in the experimental group and the implementation process made during 14 weeks are; preparing laboratory rules and test report, simple electrical circuit, resistance, series connected circuits, circuits connected in parallel, magnet and its properties, electromagnet, classification of transparent, translucent and non-transparent substances, light and color, shadow formation, laws of reflection, plane mirror, concave mirror and convex mirror.

Before starting the implementation, AAT was applied to the pre-service elementary teachers as a pre-test. Then, five different heterogeneous groups were formed in total, three groups consisting of seven people and two groups consisting of six people. Then, the course implementation process was started. Teaching was carried out based on the deductive laboratory approach. Experiment sheets were prepared by the researchers and given to pre-service elementary before each lesson. Experimental materials that pre-service elementary teachers should use in experimenting that week were kept ready on the tables. In addition, pre-service elementary eachers were provided to bring their notebooks with which they could prepare their reports when they came to the lesson. The pre-service elementary teachers carried out the experiments in the experiment sheets by following the steps in the experiment. The reports of the experiments they carried out as a group were noted individually. They also calculated the data obtained as a result of the experiment individually. After the experiments were completed, the pre-service elementary teachers were expected to write their reports about the experiment. In this report, based on the deductive laboratory approach, there are fields that pre-service elementary teachers must fill in: the name of the experiment, the purpose of the experiment, the theoretical information about the experiment, the materials used in the experiment, the conduct of the experiment, the data obtained from the experiment, the analysis of the data, the result and the evaluation. These reports were collected by the researchers at the end of the lesson from the pre-service elementary teachers who completed the experimental reports. In this way, the control group and the experimental group were tried to be balanced. Because the pre-service elementary teachers in the experimental group were not given notebooks at the end of the lesson. After the reports were collected, the experiment and the result of the experiment were discussed with the students. The implementations were carried out in the same way in all courses. After the implementation, AAT was applied again as a post-test. In order to determine the permanence of the information, AAT was applied to the pre-service elementary teachers as a retention test 4 weeks later and the process was completed.

Analysis of Data

SPSS 20 program was used in the analysis of the data obtained from the data collection tools used in the research. Normality analyzes were performed with Kolmogorov-Smirnov to determine whether the experimental and control groups were normally distributed according to AAT. In the analysis of the tests; in cases where the tests of the groups showed normal distribution ($p>0.05$), the independent-t test was used, and in cases where the tests of the single group showed normal distribution ($p>0.05$), the dependent-t test was used.

Findings

In this part of the study, the academic achievements of the pre-service elementary teachers and the analysis of the data obtained as a result of the retention test are included. The data obtained for each sub-problem created depending on the problem of the study are given below, respectively.

The first sub-problem of the study was "Is there a significant difference between the scores of the experimental and control groups from the AAT pre-test?". The normality test for the scores they got from the AAT pre-test applied to the pre-service elementary teachers was used and it was concluded that the pre-test mean scores of both groups had a normal distribution ($p>0.05$). For this purpose, the analysis was made using the independent-t-test from the parametric tests and the results of the analysis are given below.

Table 3

Independent-t-test Analysis Results of the Groups' AAT Pre-Test Scores

Groups	n	X	SS	sd	t	p
EG	30	18,40	6,355	61	-1,679	,098
CG	33	20,61	3,889			

When the above table was examined, it was determined that there was no statistically significant difference when the relationship between the groups' AAT pre-test scores was examined ($t_{61}=-1.679$; $p>0.05$). According to these findings, it can be concluded that the readiness of the pre-service elementary teachers in both groups is equal.

The second sub-problem of the study was "Is there a significant difference between the scores of the experimental and control groups from the AAT post-test?". In this direction, the normality test for the AAT post-test scores of the pre-service elementary teachers was used and it was concluded that the post-test average scores of both groups had a normal distribution ($p>0.05$). For this purpose, independent-t-test from parametric tests was used and the analysis results of this test are given below.

Table 4

Independent-t-test Analysis Results of the Groups' AAT Post-Test Scores

Groups	n	X	SS	sd	t	p
EG	30	55,20	14,226	61	3,818	,000
CG	33	43,64	9,558			

When Table 4 was examined, it was concluded that there was a significant difference in favor of the experimental group regarding the AAT post-test scores of the groups ($t_{61}=3.818$; $p<0.05$).

According to these findings, it can be concluded that the STEM education approach is a more effective method in increasing success than the deductive laboratory approach. The other sub-problem of the study was "Is there a significant difference between the average scores of the retention test of the experimental and control groups?". In this direction, since the permanence test scores of the pre-service elementary teachers have a normal distribution (p>0.05), the analysis was made using the independent t-test from the parametric tests, and the results from this analysis are given below.

Table 5

Independent-t-test Analysis Results for the Permanence Test Scores of the Groups

Groups	n	X	SS	sd	t	p
EG	30	49,33	9,589	61	3,349	,001
CG	33	40,48	11,214			

When Table 5 was examined it was concluded that there was a statistically significant difference in favor of the experimental group ($t_{61}=3.349$; $p<0.05$). According to these findings, it can be said that teaching the subjects determined in parallel in both groups according to the STEM education approach is a more permanent method than the deductive laboratory approach.

Discussion and Conclusion

The aim of this research is to determine the effects of five different modules developed in accordance with the STEM education approach and the experiments suitable for the deductive laboratory approach in parallel with these modules on the academic achievement and permanence of knowledge of the pre-service elementary teachers. The results obtained from the data in the research are discussed below, respectively.

Before the application, AAT was applied to both groups as a pre-test and it was determined that the prior knowledge levels of the two groups were equal. Similar features are observed in studies conducted in the literature and studies parallel to this study (Akçay, 2018; Aysu, 2019; Doğan, 2019; Karadeniz, 2019). In the study of Akçay (2018) conducted with 4th grade science teacher candidates, it was determined that there was no significant difference between the pre-test scores of the experimental and control group students and their prior knowledge was equivalent. In the study conducted by Aysu (2019) with 6th grade students, it was determined that there was no statistically significant difference between the pre-test scores of the experimental and control group students for the "Force and Motion" unit, and their prior knowledge was equivalent. In the study conducted by Karadeniz (2019) with 9th grade high school students, it was determined that there was no significant difference between the pre-test scores of the experimental and control group students for the "Triangles" unit, and their prior knowledge was equivalent.

After the implementation, the independent t-test was used regarding the scores of both groups from the AAT post-test, and according to the results obtained, it was seen that there was a statistically significant difference in favor of the experimental group in the post-test scores. Based on the results obtained here, it can be concluded that the STEM education approach is effective in increasing the academic achievement of pre-service teachers compared to the deductive laboratory approach. There are studies in the literature that STEM education increases academic achievement (Acar, 2018; Büyükbastımcı, 2019; Çalışıcı, 2018; Eroğlu and Bektaş, 2022; King and English, 2016; İzgi, 2020). For example; in the study conducted by Yıldırım and Selvi (2017) with 7th grade students, it was concluded that STEM activities increase academic achievement. In the study conducted by Acar (2018) with 4th grade students, it was concluded that STEM education increased the academic success of students in science and mathematics courses. In the study conducted by Çalışıcı (2018) with 8th grade students, the subjects in the unit "Living Beings and Energy Relationships" were taught with an emphasis on STEM activities in the experimental group, while in the control group, they were taught according to the current curriculum. As a result of the research, it was determined that the achievement of the experimental group students in the unit "Living Beings and Energy Relationships" was higher than the control group students to whom the current curriculum was applied. In the study conducted by Büyükbastımcı (2019) with 7th grade students, it was determined that there was a significant difference in favor of the experimental group in increasing the academic achievement of the students in the experimental group, in which STEM education for the "Force and Energy" achievement test was carried out, compared to the students in the control group, whose Science textbook was processed. These results support our study since they show similar characteristics with the results obtained from our study.

In the study conducted by Köroğlu (2019), it was determined that the significant difference in the pre-test and post-test scores of the 8th grade students in which STEM-oriented activities were applied was in favor of the post-test. In the study conducted by İzgi (2020) with 7th grade students, it was determined that the significant difference in the pre-test and post-test scores of the students was in favor of the post-test. These results support our study. In the study conducted by Karadeniz (2019), it was determined that there was a significant difference between the post-test and permanence test scores in favor of the permanence test. According to this result, it can be said that STEM activities are an effective method in ensuring the permanence of success in triangles. According to the results obtained, it can be said that permanence is provided in the groups in which the STEM education approach is applied. These results support our study.

According to the analysis results of the AAT permanence test applied to both groups 4 weeks after the implementation, it can be said that the STEM education approach is more permanent method than the deductive laboratory approach. When the literature is examined, studies have been found that STEM education provides permanence (Aysu, 2019; Doğan, 2019; Karadeniz, 2019). In the study conducted by Doğan (2019) with 7th grade students, the "Electric Energy Achievement Test" was applied to the experimental and control group students as a permanence test and it was determined that there was a significant difference in favor of the experimental group. In the study conducted by Biçer (2019) with 5th grade students, it was determined that the permanence of the information was ensured. According to these results, it can be said that the STEM education approach is more permanent than the existing methods applied in the studies. These results obtained in the studies support our study because they show similar characteristics in our study.

Recommendations

The following suggestions can be made based on the findings of this study:

- Before starting the STEM implementation, the group to which the activities will be made should be informed about STEM education, the stages of the implementation should be explained, the questions of the group should be answered and they should be understood thoroughly.
- STEM practitioners should make preparations before the implementation and take precautions against the problems that may occur during the lesson.
- Since STEM implementation are time-consuming activities, course durations should be determined accordingly.
- Both in-service training should be given to teachers and STEM education approach should be included in university programs.
- Considering that academic success and permanence of knowledge are positively related to STEM education approach, STEM activities can be included in schools. In addition, teachers can be informed about the STEM education approach.

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