A PROJECT BASED STEM ACTIVITY: LET'S BUILD A MINI FARM ON OUR SCHOOLYARD[1]

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ABSTRACT

This study aimed to present a project-based STEM activity titled "Let's Build a Mini Farm on Our Schoolyard." The activity was implemented in science and science applications courses during the 2018-2019 academic year with 28 seventh grade students attending a state school in Giresun/Turkey. At the beginning of the study, the students learned about the engineering design process and project-based learning. Then, they were challenged with building a mini chicken farm on their schoolyard, which could be a solution of a real-world problem. To complete the project, they carried out mini researches and mini designs within the unit "Reproduction, Growth, and Development of Plants and Animals." They used their knowledge and experience in STEM disciplines to design the farm. The students carried out the project activities, offered solutions to the real-world problem, selected one of these solutions, tested the solution, and solved the problem with a sustainable method.
Keywords: STEM education, living things and life, activity sample, reproduction growth and development of plants and animals, project-based learning.

PROJE TABANLI STEM ETKİNLİĞİ: OKULUMUZUN BAHÇESİNE MİNİ BİR ÇİFTLİK KURALIM

ÖZ

Bu çalışmada "Okulumuzun Bahçesine Mini Bir Çiftlik Kuralım" proje tabanlı STEM etkinliğinin sunulması amaçlanmaktadır. Etkinlik 2018-2019 eğitim öğretim yılında Giresun/Türkiye'de bir devlet ortaokulunda öğrenim gören 28 yedinci sınıf öğrencisiyle Nisan- Mayıs ayları boyunca fen bilimleri ve bilim uygulamaları derslerinde uygulanmıştır. Etkinlik öncesi bilimsel araştırma sorgulama süreci ile ilgili deneyimleri olan öğrencilere mühendislik tasarım süreci, proje yürütme süreci ve proje tabanlı STEM ile ilgili bilgiler verilmiştir. Daha sonra öğrencilere gerçek yaşam problemine çözüm olabilecek okulun bahçesine mini bir tavuk çiftliği kurmaya yönelik tasarım görevi verilmiştir. Öğrenciler projeyi tamamlayabilmek için "Bitkilerde ve Hayvanlarda Üreme, Büyüme ve Gelişme" konusu ile ilgili mini araştırmalar ve mini tasarımlar gerçekleştirmiştir. STEM disiplinlerine ilişkin bilgi ve becerilerini çiftlik tasarlamada kullanmışlardır. Öğrenciler bir STEM projesini yürütmüş, gerçek yaşam problemine yönelik çözüm üretmiş, bu çözümlerden birini seçmişler, gerçek yaşam ortamında uygulayarak değerlendirmiş ve sürdürmüşlerdir.
Anahtar kelimeler: STEM eğitimi, canlılar ve yaşam, etkinlik örneği, bitkiler ve hayvanlarda üreme ve gelişme, proje tabanlı öğrenme.

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INTRODUCTION

In recent years, Science, Technology, Engineering, and Mathematics (STEM) education which is based on the integration of the disciplines (Bybee, 2013; Breiner et al., 2012) has been the focus of educational policies, learning activities, and research studies. The development, analysis, and dissemination of these research studies have led to an increased interest in STEM activities (Wan et al., 2020). These activities are generally in the form of integrating engineering and technology disciplines into science and mathematics instruction (National Research Council [NRC], 2012).

STEM instruction typically starts with a real-world problem or an authentic project that can be solved or completed with the knowledge and skills of STEM disciplines transcending their boundaries (National Academy of Engineering [NAE] & NRC, 2014). Students are expected to solve the problem or complete the project by engaging in scientific inquiry, engineering/technology design process, or mathematical modeling (NRC, 2012). Among these processes, the engineering design consists of identifying the problem, developing possible solutions, choosing the best solution, and making and testing a prototype and is often used in mathematics and science education (Wendell et al., 2010). Although different teaching approaches are used in STEM education (Guzey et al., 2020), project-based learning (PBL) stands out as it includes working on complex and authentic tasks (Thomas, 2000).

In the PBL approach, similar to the scientific inquiry and engineering design process, students engage in determining goals and constraints, researching the content, developing and analyzing ideas, creating models, testing and improving designs, and communicating with others to solve a complex problem that requires interdisciplinary knowledge and skills (Han et al. 2016; Wan et al., 2020). Through these processes, the PBL provides contextualized authentic experiences necessary for students to construct a conceptual understanding of science, technology, engineering, and mathematics concepts. In this context, PB-STEM emerges as an integration of project and engineering design process, and it requires students to complete authentic projects using the knowledge and skills of STEM disciplines (Capraro & Slough, 2013). In PB-STEM, students develop a product to solve a meaningful real-world problem. Hence, the project task/challenge also includes an engineering design process (Wan et al., 2020). In this approach, scientific inquiry, engineering design process, and project-based learning are carried out simultaneously and intertwined under the guidance of a teacher. Thus, along with students' meaningful learning of science and mathematics concepts, their skills, interests, motivations, attitudes, and career awareness also develop (Chen & Chang 2018; Han et al., 2016; Wan et al., 2020).

Research studies examined the design and implementation of the PB-STEM approach and reported its positive outcomes for students' learning (Bell, 2010; Horton et al., 2006; Merrill & Comerford, 2004; Schooler, 2004). However, some studies revealed that science teachers found it challenging to plan and implement project-based learning and/or STEM activities (Bozkurt Altan & Hacıoğlu, 2019; Hacıoğlu & Başpınar, 2020; Wilhelm et al., 2019). These findings point out the importance of developing and sharing PB-STEM activities with teachers to support them in implementing STEM education. In particular, there are limited activities on the concept of living things and life in biology (Roehrig et al., 2021). Therefore, presenting examples of PB-STEM activities on the concept of living things and life and describing the learning environment designed for implementing these activities might encourage more teachers to practice STEM education.

ACTIVITY IMPLEMENTATION

This study aimed to present a PB-STEM activity that addresses the curriculum standards within the "Reproduction, Growth, and Development of Plants and Animals" unit in the seventh-grade science curriculum (Ministry of National Education [MoNE], 2018). The activity was developed as part of the master's thesis completed by the first author under the supervision of the second author. More detailed information about the activity can be found in the first author's master's thesis (Adanır, 2021).

After obtaining the necessary legal permissions, the activity was implemented by the first author (science teacher) under the guidance of the second author, with 28 volunteer seventh-grade students (15 girls, 13 boys) attending a state middle school in Giresun (a province of Turkey) in the 2018-2019 academic year. The students formed groups of 5-6 members and worked with their group members during the activity. There were five groups in total. The students named their groups Sunflowers (S), Pumpkins (P), Chicks (C), Nettles (N), and Jackals (J). The researchers coded the students with their group names and student number. For example, the students in the Nettles group were coded as N1, N2, N3, N4, and N5. The activity was implemented in the classroom (18 lesson hours within the science and science applications courses) and outside the classroom in a two-month (8 weeks) period in April-May 2019.

Materials

During the implementation of the activity, the following tools and equipment were used:

- ❖ STEM activity booklet "Reproduction, Growth, and Development of Plants and Animals" prepared by the researchers,
- ❖ teaching materials (smartboard, tablet, phone, computer, resource books, etc.),
- ❖ stationery materials (ruler, cardboard, pushpin),
- ❖ green space to build the farm,
- ❖ garden, farm supplies (hoe, shovel, vegetable crates, plant seeds, seedlings, water, straw, etc.), and
- ❖ construction and building materials (brick, cement, sand).

In the activity, the students were challenged with building a mini-farm where they can produce organic eggs and food, ensuring the reproduction, growth, and development of plants and animals. For the students to complete this challenge, they were given information about project-based learning (Capraro & Slough, 2013; Han et al. 2016; Wan et al., 2020) and the engineering design process (Wendell et al., 2010). Additionally, since this is a complex project, students' learning was scaffolded by including mini-research and mini-designs as recommended by Wendell et al. (2010) for design-based science education. Aligned with the engineering design process, the students suggested solutions for their farm design, evaluated these suggestions, and decided on the farm they would build as a class. Next, the students built the farm. They worked on the reproduction, growth, and development of plants and animals in the farm for 3 weeks to ensure sustainability. Lastly, the students evaluated their projects. Figure 1 shows the activity implementation model.

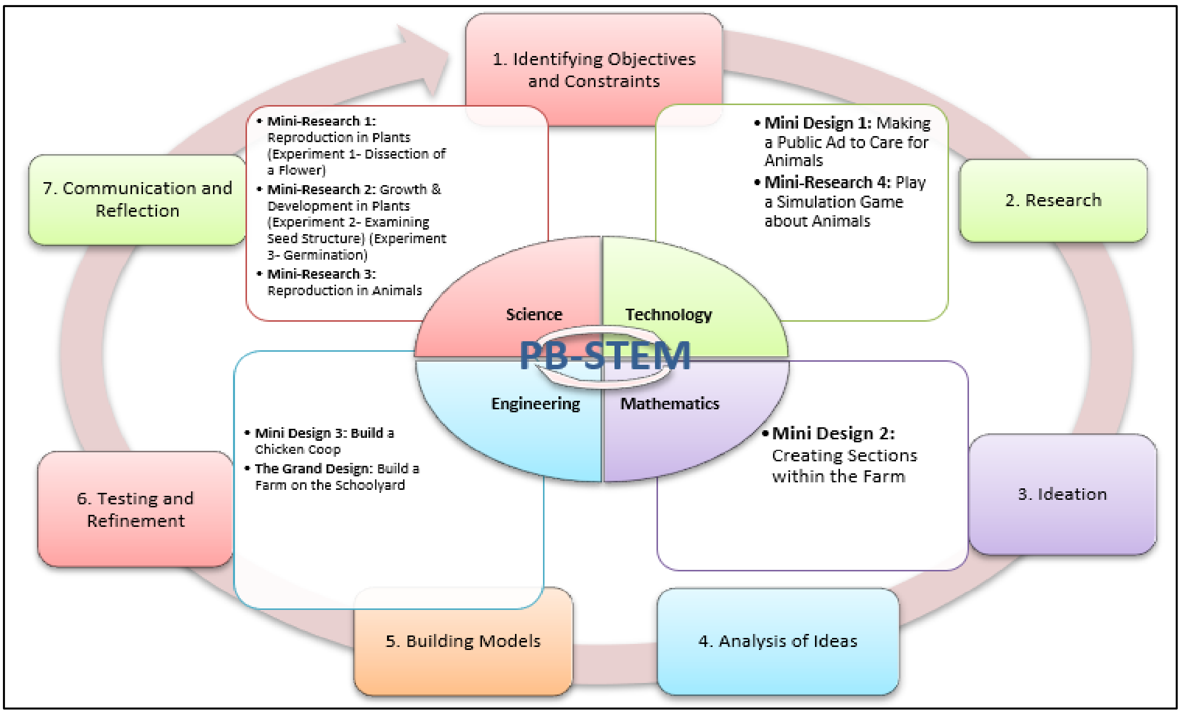


Figure 1. The PB-STEM Model Implemented in the Activity

1. Identifying Objectives and Constraints

This phase took 2 lesson hours and started with showing the students some real-world problems from various newspapers. The news articles discussed the negative effects of not consuming organic products on human health and the environment. Students shared ideas on what to do to solve these problems and proposed, "We should grow our own fresh and healthy food." Afterward, the teacher assigned the students a challenge (Figure 2) that asked them to build a chicken farm in their schoolyard. They were also asked to ensure the sustainability of the farm by feeding the chickens with organic food.

> You are agricultural engineers assigned to build a farm for organic egg production using the space allocated to us in our school's hobby garden. You are expected to start a garden to grow healthy vegetables to feed the chicks and chickens so that you may get organic eggs. You are also expected to construct safe housing for the chicks and chickens so that they are not eaten by other animals. Ensuring the healthy reproduction of the chickens is another requirement of this project. You should recycle to create no waste in your environment-friendly farm. The budget for this project is limited. Now, let's solve this problem together!

Figure 2. PB-STEM Challenge

Students were asked to identify the criteria and constraints of the project task. The students determined criteria such as clean soil and healthy food and identified the budget as a constraint. The answer of a group is given in Figure 3 as an example.

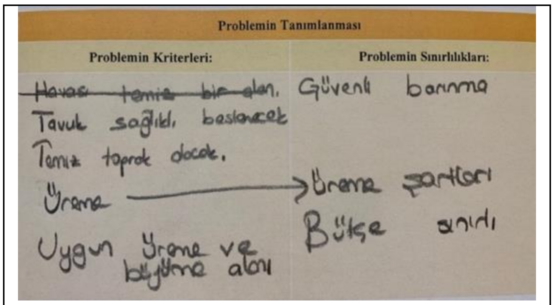


Figure 3. Examples of Criteria and Constraints

2. Research

This phase lasted 9 lesson hours and included activities outside of the classroom. To help the students notice that they need scientific information to carry out the project, the teacher asked them to discuss ideas on how to build and sustain their farm. During this discussion, the students realized their lack of knowledge on farming and that they were not able to elaborate on the subject. For example, Jackals had the following conversation:

> J3: Let's raise worms to feed the chickens.
> J1: Chickens eat beets. We need to feed them with vegetables. Do they eat worms? If they do, how will we raise them?
> J3: How are we going to grow beets? Will we buy it from the market? We do not have enough budget.

To facilitate the students' discussion and inquiry, the teacher asked: "What do we know to build our mini-class farm? What do we need to know?" Each group completed a table to answer these two questions (Figure 4). One group, for example, wrote that they knew chickens need to live in a safe place and eat plants, but they did not know what chicks eat and how chickens reproduce.

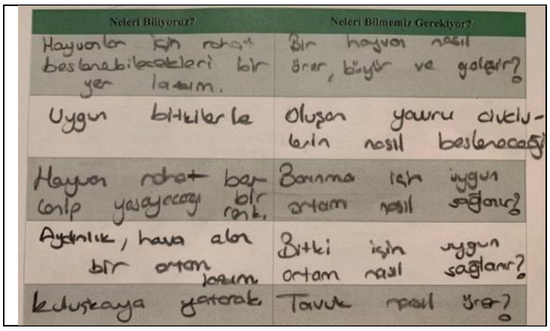


Figure 4. A Group's Know-Want to Know Chart

The students wrote research questions while completing the table given in Figure 4. The teacher guided the discussions so that the students wrote research questions that led to the mini-research and designs given in Figure 1. In addition, the teacher explained to the students that the research process should be planned gradually due to the complex nature of the project work as they have to answer more than one research question.

Next, the research phase began, and the students worked on each research question to learn the necessary knowledge and skills to carry out the project. Table 1 shows the research process that the students completed under the guidance of the teacher.

3. Ideation

Once the students completed the research process, each student planned an individual solution in light of the criteria and constraints of the problem/the design challenge. Figure 5 presents an example solution. The students were asked to use the knowledge they learned from the research phase and to explain their solution in detail, including how it could contribute to the project. The ideation phase lasted 2 lesson hours.

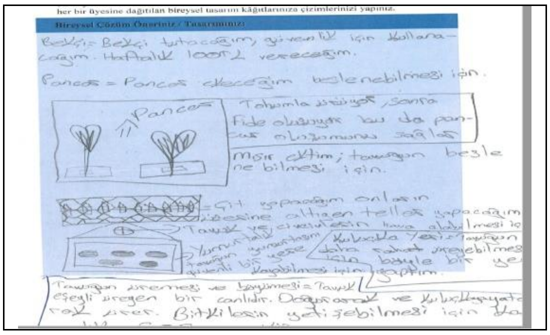
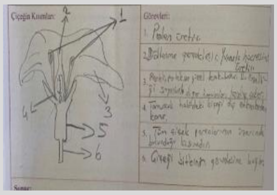
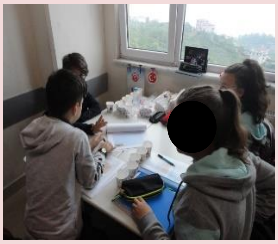
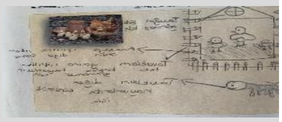


Figure 5. An Individual Solution Plan

Table 1. Mini Design and Research Process and Examples of Student Work

Mini Research 1: Reproduction in Plants (Experiment 1- Dissection of a Flower) Since it is necessary to grow organic plants to feed the chickens with healthy food, the students researched the types and conditions of reproduction in plants. They answered questions such as "The fruit trees in our neighborhood have flowers. What is the importance of these flowers? Will we need flowering plants on our farm? Why?" The reproductive parts of the flowering plants brought to the class were dissected.	
Mini Research 2: Growth and Development in Plants (Experiment 2- Examining Seed Structure, Experiment 3- Germination) The students inquired about the growth and development processes of plants. For this pupose, they examined the structures of the seeds brought to the class and conducted an experiment to control the conditions necessary for the germination of a seed. They formed research questions and determined the dependent, independent, and control variables. During the experiment, data were collected and analyzed. A germination graph was created on reflective journals. The students interpreted the data and determined the necessary conditions for germination.	
Mini Design 1: Ensuring the Growth and Development of a Plant of Our Choice: The students designed the environmental conditions needed for the growth and development of a plant. The students took care of their plant for one week, wrote their observations in the reflective journals, and conjectured the necessary environmental conditions for the growth and development of the plant.	
Mini Research 3: Reproduction, Growth, and Development in Animals: Considering that chickens not only eat plant-based foods but also animal-based foods, the students investigated the reproduction, growth, and development conditions of animals using websites, textbooks, and supplementary sources. They also played simulation games about the growth and development of animals to deepen their learning.	
Mini Design 2: Making a Public Ad to Care for an Animal: To integrate technology into the project lessons, the teacher asked the student groups to create a public service advertisement about how to care for an animal. The groups designed their public advertisement by examining the living conditions of animals in their environment and presented their advertisement to the whole class.	
Mini Design 3: Creating Sections within the Farm Garden: This task promoted mathematics integration by asking students to create a mathematical model that shows the division of the farm into different sections. The students used cardboard and showed the sections of the farm reserved for plants and animals proportional to the actual measurements. By using ratio and area calculations, the students discussed how many plants and animals they could have on their farm.	
Mini Design 4: Build a Chicken Coop: The students designed a cost-effective, environmental-friendly coop for chickens to live in a healthy and safe environment. The students determined the size and materials of the coop as well as where to build it on the farm.	
At the end of each mini-research and mini-design, the students discussed how to use their new knowledge and skills to complete the project.	

4. Analysis of Ideas

In this phase, which took 2 lesson hours, the students evaluated their solutions according to the criteria and constraints they had determined at the beginning of the engineering design and identified the best solution. Decision matrices were given to the groups to facilitate their decision-making process. Like engineers, the students created decision matrices to select the best solution that meets the most criteria and overcome the constraints (Figure 6).

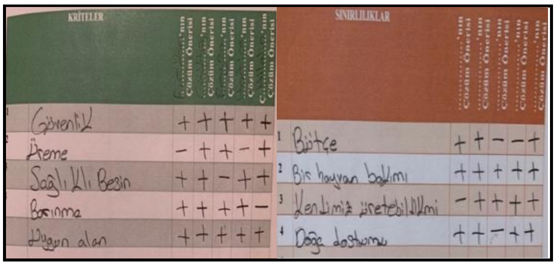


Figure 6. One Group's Decision Matrix

During the decision-making process, the students took into account the growth period of the plants and the food that chickens eat. For example, an excerpt from the Jackals group's discussion is as follows:

J1: We should plant barley. This way, the chickens will have the food in a short amount of time because it grows fast.

J3: Then why do we plant seeds? If we sow lettuce seedlings, we do not have to wait for the time it takes for the seed to germinate and become a young plant. Chickens eat lettuce as well.

J6: Then, we can use lettuce in the first days when we build the farm. Later on, barley will grow, and we can use it.

J4: As an animal source of food, worms that reproduce by regeneration can be useful.

During the analysis of different solutions, some groups preferred to use seeds to feed the chickens, and some other groups decided to use seedlings to shorten the growth period. Some students suggested using the germinated seeds they used in the germination experiment. Photograph 1 shows an image from this phase, and Figure 7 presents the best solution selected by one group.

Since it was not possible to implement all the best solutions identified by the groups, the whole class selected the best solution among the groups' selections. For this to occur, each group presented its best solution to the whole class. For example, the Pumpkins Group presented their solution as follows:

P5: We decided to have 5 chickens and 1 rooster on the farm. It is important to have a male and female to ensure the continuity of the generation. We think that the space will be enough. We also think that it will be suitable for the budget.

P1: We preferred to sow seedlings to grow healthy food. Using seeds would waste time in terms of growth and development.

P2: We chose to grow mint because it easily reproduces with vegetative propagation. It is also effective to get good eggs.


Photograph 1. An Image from the Analysis of Ideas Phase

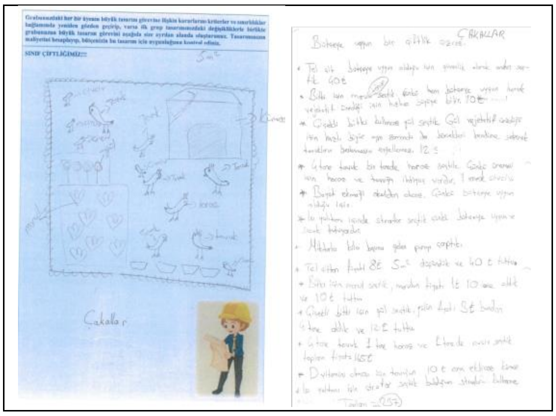


Figure 7. One Group's Best Solution

In this phase, the students used science knowledge to analyze the solutions and defended their arguments with scientific reasoning to answer the questions posed by the teacher or other students. Thus, the students had the opportunity to evaluate both their own and peers' learning. For example, they evaluated the solution presented by the Chicks group as follows:

J3: Since glass wool is used to insulate the coop, I think it is not environmental-friendly. However, their plan to use the leftover food in the cafeteria is important in order not to create waste. I think, overall, it is an environmental-friendly farm.

N1: They selected organic products, although it negatively influenced the budget. In this way, they can have nutritious eggs.

S4: Sexual reproduction is important for the continuity of the generation. They included chicken (female) and rooster (male) in the coop. Instead of only plant-based food, they used insects from the garden and worms that reproduce asexually by regeneration. I believe that the eggs will have high nutritional value.

Each group's solution was rated with the participation of all students by using the rubric written on the class board (Photograph 2). The solution plan that met the most criteria and overcame the constraints, thus received the highest rating, was selected as the best solution. The class shared ideas to further enhance the selected solution and devised a plan to implement it to complete the project.

Photograph 2. Images from Selecting the Best Solution Phase

Due to having limited time, the students decided to buy healthy chickens to ensure the healthy growth, development, and reproduction of chickens. Regarding the food to feed the chickens, they agreed on using the seedlings that they had grown during the mini-research and design process, buying seedlings grown from reliable seeds from the local town, and planting seeds that sprout quickly. The students discussed how to ensure the sustainability of the farm. In addition, they paid attention to using the budget economically and revised the solution plan by reviewing the construction market catalog provided by the teacher. Finally, the students divided work among each other to put the best solution into practice. Once the solution was finalized, the next phase began.

5. Building Models

This phase lasted 2 lesson hours and included activities outside of the classroom (Photograph 3). The students worked collaboratively to build their farm. The equipment was provided by the teacher. Other students in the school and the school staff helped, particularly with the construction of the coop. The farm was built quickly as a result of collaborative work.

Photograph 3. Images from Building the Farm Phase

While building the farm, some groups preferred to grow the plants from seed, while some groups sowed seedlings obtained from reliable places to accelerate the food production process due to the limited time for the project. In addition, they propagated vegetatively reproducing plants that were already in the garden such as mint and purslane using both seedlings and seeds. Since it is necessary to raise healthy chickens for nutritious eggs, the students tried to be careful to use high-quality seeds. In particular, they avoided using genetically modified organisms. The ancestral seeds, which some of the students' families kept with the seed preservation technique that they have been using for generations, were brought to school and planted in the garden. The groups, who think that chickens should not be fed only with plants, emphasized that insects and worms available in the garden are good animal source foods for the chickens. In addition, the students increased the quality of the garden soil by using natural cow manure and did not use any chemicals. They planned to use chicken manure as an organic fertilizer the next time. In this way, the students made plans for the sustainability of the farm with the guidance of the teacher.

Although it seemed like both the project and the science unit ended when the farm was completed, the students' work continued outside the classroom. They took care of the plants and animals living on the farm.

6. Testing and Refinement

Before the testing and refinement phase, which lasted for 1 lesson hour, the students were asked to evaluate their projects. They were given 3 weeks for the evaluation of the project/farm design and the sustainability of the farm. In this process, the students continued to take care of the plants and animals on the farm during the extracurricular times by cooperating among themselves and getting support from the school staff. They used the plants grown to feed the chickens, shared the eggs they got from chickens, took them to their families, and felt the pleasure of being productive. Unfortunately, the students could not ensure the reproduction of chickens due to the end of the school term. However, they realized that the eggs they collected from the farm are reproductive cells of chickens. At the end of 3 weeks, the teacher and the students came together in a 1-hour lesson and evaluated the farm by considering the project requirements. The students said that they decreased the cost by feeding the chickens with fast-growing plants (C1), and they also got eggs from chickens. They decided to grow plants according to seasonal conditions (S2), reproduce the existing worms in the garden by regeneration and use them as animal source food (N5), and raise baby chicks by incubating chicken eggs (J4) in the future. In addition, they decided to grow not only herbaceous plants but also woody perennial plants that will allow chickens and chicks to roam freely (N2). S1 suggested that they could plant the seeds of the fruits they eat in the cafeteria for this purpose. Instead of buying chickens, they planned to look after the chickens raised by K3's family on the farm (P1) and use the food leftover in the cafeteria (P2). Lastly, the students agreed that those whose homes are close to the school could help the school staff with the farm work during the summer break.

7. Communication and Reflection

Communication and reflection took place at all phases of the activity. Therefore, it should not be considered as a phase that took place only at the end of the project. The students communicated and shared ideas with each other at all phases of the project, from identifying the objectives and constraints to the testing and refinement phase. They presented solution plans to each other and evaluated each other's work. While the continuity of this phase allowed to focus on process evaluation, it also provided the opportunity for students to make self and peer-assessment. The teacher was also able to formatively and summatively assess the students' progress and provided feedback to scaffold their learning.

EVALUATION of the ACTIVITY

At the end of the project, the students were asked to express their opinions about the whole process. For this purpose, the teacher conducted an unstructured whole class interview with the students by asking, "What are your positive and negative views about completing the project?"

The analysis of students' responses revealed some common themes. For example, a group of students focused on conceptual learning and expressed the view that they had permanent learning as a result of participating in the project activities:

> S2: When we do an activity, I remember the concepts more. I get bored in the lessons, but not in the activity. It is beneficial because I am both learning and applying.
>
> P2: When we first drafted a solution, we couldn't come up with a good project idea because we didn't have enough knowledge on the topic. We started to think more comprehensively by enhancing our knowledge through mini [research and design] activities.
>
> J6: I grasped the content better. Taking care of the plants and animals made my learning easier. Now, I have a better comprehension of the content.
>
> N5: I could store more information in my mind becasue I practiced what I was learning.
>
> C1: Practical activities like this are very good in my opinion. The regular lessons are boring.

Some students spoke about the positive effect of the project on their interest and attitudes towards the lesson. They explained that the lessons were more fun, they enjoyed being active in the research process, and they were excited to discover new knowledge:

> C4: It was fun, particularly the parts that included building a garden and a coop because I didn't just acquire knowledge, I applied it.
>
> C3: I was more interested and excited compared to other content. I had the opportunity to learn the content deeper by researching and applying.
>
> N1: Science lessons were boring in the past. We got very tired, but the activities were good. We have obtained permanent knowledge.

Some of the students focused on the skill development during the PB-STEM process and expressed the view that they developed their skills such as inquiring, modeling, using mathematics and technology, working collaboratively, and problem-solving:

> C3: When there is a problem, I should first obtain knowledge and then start solving the problem.
>
> J2: It has added convenience to my life, helped me discover how I should think about how to feed and raise animals when I take on animal care to ensure their safety.
>
> N2: My mathematical skills have improved because we modeled the coop using actual measurements and performed budget calculations.
>
> P1: Preparing the Powtoon presentation developed our technological knowledge. We also played digital games. We brought our mobile phones to school and used them during the research process.
>
> N4: I loved the group work and enjoyed learning from my friends.

Some students stated that their interest in the engineering profession increased during the activity, and now they understand better how an engineer works:

> C2: It's good to be an engineer because we design the products ourselves.
>
> J2: Engineers have a tough job. However, I have realized that it is necessary to be very good at finding solutions to real-world problems, that we need to consider each factor in detail.
>
> P4: I was thinking that an engineer would fill out forms and give information. After this lesson, I realized that it is a better occupation. Because they first do the planning, then research, and finally implement.

Supporting the view of J2, it was among the researcher's notes that the students had difficulties in defining the problem, determining the criteria and constraints, and deciding on the best solution due to a lack of prior experience. In the current study, the teacher's guiding and motivating approach played an important role.

The project was completed as part of the science and science applications courses, which were taught by the science teacher. In addition to the lesson hours, the students had to complete a significant amount of extracurricular work. Some students shared negative opinions about spending a lot of time and effort, even though they thought it was worth it. They suggested that mini-research and mini-designs related to mathematics and technology could be done in mathematics and information technologies courses. An opinion representing this idea is as follows:

> P4: We got too tired because we studied all the disciplines in the science class. I wish we completed the math part in the math class and the presentations in the information technology class.

CONCLUSION and SUGGESTIONS

In this PB-STEM activity, the students completed a project that involved building a mini-farm in their schoolyard to solve the problem of difficulty of finding healthy foods that they may encounter in real world. The students were engaged in both the project-based learning and the engineering design process to complete the design challenge that was related to real world, required interdisciplinary knowledge and skills, had criteria and constraints, and had more than one solution method. During the PB-STEM activity, the students learned the types of reproduction in plants and animals, explained the growth and development of plants and animals with examples, learned the factors that affect the growth and development of plants and animals, and reported the process of taking care of a plant or an animal. To reach these learning outcomes, the students inquired about animal and plant life, experienced the scientific inquiry process, conducted experiments, and used the results they obtained to design and build the farm. The project-based learning and the engineering design process provide an opportunity for learners to apply knowledge to real-world situations (Thomas, 2000; NRC, 2012). Indeed, as problem-based learning, STEM, and PB-STEM activities improve students' knowledge and skills and increase their motivation and attitudes towards the lesson (Han et al., 2015; Han et al., 2016; Kwon et al., 2021; Miller & Krajcik, 2019; NRC, 2012; Tati et al., 2017; Wan et al., 2020), the activity used in the current study might have similar effects on students' learning. This is supported by the previous research studies (Blair, 2009; Fifolt & Morgan, 2019; Williams & Dixon, 2013) reporting that gardening practices involving plants and animals are positive learning environments that help students learn about living things and life.

The students actively participated in the project activities by taking responsibility for their learning, applying the concepts learned, taking care of animals, and growing plants. The PB-STEM provided them with a learning experience in and outside the classroom, different from their past schooling experiences. The first researcher (the science teacher) observed that this approach gave them a sense of belonging. The students took ownership of their tasks and completed them on time. It was also observed that each of the students took a leadership role in different phases of the project. These findings are supported by the study conducted by Fifolt and Morgan (2019) with primary and secondary school students who engaged in a school farm activity designed based on a scientific inquiry approach.

The project tasks used in the current study can be revised and used with students at different grade levels, taking into account the environmental context in which the students live. The integration of more disciplines may also be considered in enhancing the current project. In this study, the integration of science and engineering was more prominent than the integration of technology and mathematics. This aspect of the project task can be improved if Yıldırım and Selvi's (2017) argument that all STEM disciplines should be included in PB-STEM activities is considered as a criticism. However, from the "definition of STEM education as the integration of at least two disciplines" point of view, the current project task does not have a limitation regarding the integration of the disciplines. Nevertheless, we can offer our suggestions as researchers in this field. To further strengthen the integration of the mathematics discipline, the project can continue with the activity designed by Selmer et al. (2014). Accordingly, students might sell the vegetables, fruits, eggs, and chickens they grow on the farm in the neighborhood market. Such a revision might enhance students' statistical literacy and entrepreneurial skills. Additionally, ecological literacy goals, which are important competencies for biology and environmental education, can also be taken into account. To strengthen the technology integration process, the same project can be implemented using digital games in the virtual environment. Similar to the activity designed by Hacıoğlu and Dönmez Usta (2020), students might be engaged in the task of designing a farm in a digital game. However, we should note that all these suggestions necessitate time and modification of the learning environment. A final suggestion is to have students monitor the growth and development of plants and animals using technological literacy skills. To improve the farm performance, students can use sensors to check soil fertility, water status, and mineral balance. Similarly, fertilization and irrigation processes can be done with the help of sensors. Additionally, temperature sensors can be used to control the temperature of the environment, which is important for the growth and development of chicks.

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