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LET'S FORM A REFLEX ARC MODEL: A STEM ACTIVITY[1]

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ABSTRACT

The purpose of this study is to introduce an activity which has been designed in accordance with Science, Technology, Engineering, Mathematics (STEM) education within the scope of 5E learning model and to present the implementation steps of it. The activity plan is on the topics of Nerves, Hormones and Homeostasis in Human Physiology Unit in 11th grade biology curriculum. The activity was implemented with the participation of 49 students at a public high school. For the implementation of the activity, the students were divided into groups of five and they tried to complete the activity in four class hours. The participant students stated that they both learned and enjoyed learning while they were creating their model. Moreover, the teachers who implemented the activity stated that the equipment used in the activity is easy to access, which creates an advantage for the activity to be done in class.
Keywords: biology education, reflex arc, STEM, nervous system.

REFLEKS YAYI MODELİ OLUŞTURALIM: BİR STEM ETKİNLİĞİ

ÖZ

Bu çalışmanın amacı STEM eğitimine uygun olarak tasarlanan bir etkinliğin 5E öğrenme modeli kapsamında tanıtılması ve uygulama basamaklarının sunulmasıdır. Etkinlik planı, 11. Sınıf Biyoloji Dersi Öğretim Programında bulunan İnsan Fizyolojisi ünitesindeki Sinirler, Hormonlar ve Homeostazi konusu ile ilgilidir. Etkinliğin özellikle, omuriliğin görevleri ile refleks yayının çalışma mekanizmalarının öğrenilmesi noktasında faydalı olacağı düşünülmüştür. Etkinlik, bir devlet lisesinde öğrenim gören 49 öğrencinin katılımıyla gerçekleştirilmiştir. Etkinliğin uygulanmasında öğrenciler beşer kişilik gruplar oluşturmuş ve dört ders saati boyunca etkinliği tamamlamaya çalışmışlardır. Etkinliği uygulayan öğrenciler ürün oluştururken hem öğrendiklerini hem de öğrenirken zevk aldıklarını ifade etmişlerdir. Ayrıca, uygulamayı yaptıran öğetmenler etkinlikte kullanılan malzemelerin kolay ulaşılabilir özellikte olmasının da etkinliğin yapılabilmesi için bir avantaj olduğunu belirtmişlerdir.
Anahtar kelimeler: biyoloji eğitimi, refleks yayı, STEM, sinir sistemi.

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INTRODUCTION

In today's understanding of education, rather than the direct transfer of information from the teacher to the students, students' reaching information by interpreting the findings they have obtained after researching, questioning and doing various activities is more emphasized. For this reason, in the renewed curricula and the textbooks, there are many experiments, research tasks and activities during which students will have a chance to become more active. Also, in Turkey, both elementary and secondary science curricula were updated at certain times and the subject matters and the titles were reorganized. Since the 2018 education year, the updated biology curriculum has been implemented at high school level. In the updated biology curriculum, it is aimed to enable students to evaluate scientific discussions concerning the individuals and society by acquiring the basic knowledge about biology and science, to use that knowledge actively and create unique products, to take part in functional projects by suggesting new ideas and discover the link between biology/science and technological developments (Ministry of National Education [MoNE], 2018). In line with this, many researchers, educators and teachers have been conducting various scientific studies and have included activities based on Science, Technology, Engineering, and Mathematics (STEM) education in these studies.

STEM education is defined as students' effort to form the link among the fields of science, technology, engineering, and mathematics based on the problems that they are faced with in daily life (Stohlmann, Moore, & Roehrig, 2012). In addition, STEM education is also regarded as a type of education which covers quality learning by bringing the disciplines together, using the existing knowledge in daily life, improving life skills, employing higher order thinking skills, and critical thinking (Yıldırım & Altun, 2015). Moreover, STEM education, which covers four important disciplines, is also defined as a learning-teaching model which includes interdisciplinary implementation (Akgündüz et.al, 2015; Bybee, 2010). STEM education, which has started to be implemented in many countries all over the world, and particularly in the United States of America, is considered important in terms of having a competitive economy from the perspective of other countries and bringing the country's citizens to a level where they can catch up with the requirements and developments of the era (Corlu, Capraro, & Capraro, 2014; Sanders, 2009). The reason is that STEM education is seen as an education system which pursues innovations and the students in this system have an educational environment where they solve problems regarding real life and create opportunities (Chute, 2009). In the competitive economic conditions of the countries in today's world, in order for societies to be able to follow the advances in science and technology, sustain development and increase the level of welfare, individuals are required to have the ability to question, to think critically, to find the best solution to the problems they are faced with and to create by internalizing their own culture. The intention to raise scientifically literate individuals who not only can acquire the basic knowledge and concepts, but also can create new designs or can improve the existing designs in the light of this knowledge resulted in the inclusion of STEM education in educational curricula. It is especially emphasized in the implementations of STEM education that students should actively participate in the process of product design and creation, should be aware of which resources they need in order to design the product, and should determine which problem in daily life the designed product is going to offer a solution to (National Research Council [NRC], 2012). The students who actively take part in the whole process should, of course, generate ideas and share them, create the designed models and test them within the process summarized above.

In the literature on STEM education, it is possible to come across a lot of information about its definition, purpose and necessity. However, the benefits of STEM implementations in general can be summarized as follows: it provides a refreshing learning environment, it encourages students to think with flexibility and self-confidence, it supports students to discover, research, understand the world and contribute to it, it improves their problem-solving skills, causes students to be more enthusiastic and more interested in science, mathematics and other scientific fields by using design and engineering and is a key to scientific literacy (Morrison, 2006).

Many studies on STEM education have been conducted both at national and international levels. There is a tendency in curricula towards integrating STEM education (Çepni & Ormancı, 2018). In the related literature, some definitions about the implementation of STEM education are made and two types of important integration, namely context and content integration, are mentioned (Roehrig, Moore, Wang, & Park, 2012). In both integration models, the contribution of the disciplines that belong to STEM is observed. However, context integration focuses on creating a context with the help of other disciplines especially to make the teaching of a lesson topic from a certain discipline more meaningful and clear, while content integration concentrates on the use of STEM disciplines in teaching a lesson topic in every unit or the inclusion of learning objectives from more than one STEM discipline (Moore et al., 2014; Roehrig et al., 2012). Context integration reveals the interdisciplinary links in order to make students' learning more meaningful, but does not have to directly address the learning objectives of all the disciplines that form the context. The activity presented within the scope of this study focused on the reflex and the reflex arc which belong to the discipline of biology (science) and aimed to create a context with the disciplines of mathematics, technology and engineering in order for the students to learn the lesson topic in a more meaningful manner. In the related literature, there are STEM activities that were designed and implemented in this way (e.g., Aydın-Günbatar, 2018). It is thought that the activity implemented in the current study would be useful for both teachers and students since it enables the teaching of the concepts regarding the functions of the spinal cord and reflex through a concrete model.

There are many learning-teaching models about the implementation of STEM education such as problem-based, argumentation, and inquiry-based learning. The 5E learning model is employed in this study. The 5E model was suggested by Karplus and Thier (1967) and developed by Roger Bybee in the following years as part of the Biological Sciences Curriculum Study – BSCS (Bybee et al., 2006). The 5E model, which expects students to discover the concepts, feel the responsibility for their own learning, form the link between the newly-learned information and the existing information during the constructive learning process, consists of five steps: engagement, exploration, explanation, elaboration, and evaluation.

In the *engagement step*, it is especially aimed to attract the students' attention and interest in the lesson and arouse curiosity. With the help of the activity, problem set or various visuals, students' pre-knowledge is activated (Boddy, Watson, & Aubusson, 2003). In the *exploration step*, students make observations and do research, suggest hypotheses regarding the topic, plan various activities and implement them. Especially in the exploration step, students actively participate in the lesson and try to put the information they have acquired into practice. In the *explanation step*, students are encouraged to share the acquired information in classroom environment under the guidance of teachers and the concepts regarding the topic are clarified. The concepts and terms regarding the topic are highlighted and explained, particularly related to the hypotheses formed, the activities conducted, and the models created in the exploration step. The teachers' guidance is essential for the concepts to be explained and the generalizations to be made in such a way that they are scientific, accurate, and valid (Tonseenon, 2017).

In the *elaboration step*, it is aimed to establish the link between the acquired information regarding the topic and daily life. In this stage, teacher may ask questions to students regarding the use of the information or to make suggestions for the solution to a new problem set. In the *evaluation step*, learning concerning the topic is evaluated. In this step, teachers evaluate students' learning, but the students can also evaluate their own learning. In this evaluation step, both the traditional and alternative assessment tools can be employed (Bybee, 1997). Within the scope of this study, the 5E model, explained above, was used. It was aimed to teach students the basic concepts regarding reflex and the reflex arc in steps.

The Reflex Action and the Reflex Arc

Reflex actions are quick and involuntary responses to external stimuli. Reflexes take place with the help of receptors, sensory neurons, associated neurons, motor neurons and effector neurons (muscles or glands). The nerve

pathway covering two or more neurons through which the impulse travels when the reflex takes place is called the reflex arc. For example, when somebody hits our knee-jerk, we give a response to the stimulus before our brain responds and causes us to feel pain because the response in this situation is generated in the spinal cord, not in the brain. Reflexes such as the knee-jerk reflex, the sucking reflex of the baby or the pupil reflex depending on the amount of light are given as examples of innate reflexes, while behaviors such as swimming, playing the piano and riding a bike are examples of learned reflexes, which are learned by the brain and controlled by the spinal cord (Purves, Orians, Heller, & Sadava, 1997).

The activity developed in the current study is related to the science standard "the functions of the spinal cord and the reflex arc are explained and the importance of the reflexes for the human life is highlighted." This standard is included in the Human Physiology Unit of the 11th grade Biology course (MoNE, 2013, p.15; MoNE, 2018).

ACTIVITY IMPLEMENTATION

After the necessary legal permissions had been taken and with the permission and approval of the teachers who would implement the activity, it was conducted with 49 high school students from two classes at a public high school in Turkey. The activity was implemented in two classes of a biology teacher. Before teaching the activity, the biology teacher had been informed about both STEM and the 5E learning model. Researchers provided training on the application steps and clarified the important concepts in practice. The worksheet for the implementation of the activity had been prepared by the researchers. The students were divided into small groups including five students and the activity was completed in 4 class hours (i.e., 4x40 minutes).

Tools and Materials Used in the Activity

A supply pool was prepared in classes in order to conduct the activity. During the activity, the teacher did not tell the students which material would be used in the activity. The students chose the tools which would enable them to test their hypotheses and create the models that they would design from the pool by themselves. The tools that did not exist in the pool but were considered necessary by the students to create their models were later added to the pool. The tools in the supply pool included

- battery,
- battery holder,
- conductive wires in different diameters,
- bulb,
- cardboard,
- craft paper,
- play dough,
- glue,
- scissors,
- colored pencils,
- electric motor, and
- motion-sensitive sensor.

The activity was conducted in order to explain the reflex arc and to highlight the importance of the reflexes in human life. The teaching and learning process is explained below according to the 5E learning model.

Engagement

In this stage, the purpose was to attract the students' attention and interest and to reveal their pre-knowledge regarding the topic of reflexes. Firstly, the students were shown a toy which kicks when you step on its hand. The students were asked how the quick response that the toy baby gave takes place in our body. Students discussed this question within their groups and wrote their answers on the worksheet (Appendix 1). The groups then shared their answers with the class. The students responded to this question by giving examples of reflexes in humans. For example, one group wrote "Yes, it is possible, the same response occurs in our kneecap."

Then, the students were asked how they respond when they are exposed to a loud noise suddenly or a sudden action and their answers were discussed in class. Moreover, the students were asked to watch a short cartoon (Abayhan, 2013) on classical conditioning and to comment on the reasons for the events that take place in the cartoon.

At this stage of the 5E model, the students were asked to fill out the first two parts of the KWL (What I know? What I want to learn? What I have learned?) table (Appendix 1) and they

were required to write their pre-knowledge about the reflex action and the reflex arc and what they want to learn. Students wrote about the role of brain and spinal cord and they provided examples of reflex action and asked questions about the reflex. For instance, one group wrote "We close our eyelids with a reflex in a sudden sound or movement." in the What I know column and "How does reflex occur?" in the What I want to learn column.

Exploration

At this stage, the students formed groups of five. They were asked to carry out a modelling study regarding the problem set in their worksheets. The most important point that the students needed to pay attention to during the design process (showing neural conduction) was that the responses we give to sudden actions in daily life might be a reflex and in order for a reflex to take place, minimum two neurons among sensory neurons, associated neurons, and motor neurons need to work. Therefore, they were expected to realize that they needed to be careful to include neuron types in their models.

The case that was given to the students was as follows:

> Mister Ferhat works as a chef at the school cafeteria. One day, he had a traffic accident when coming back home from work. After the treatment period, he returned to his job. However, although he holds hot objects with his right hand all the time, he never feels pain. He realizes the burns on his hand only after he feels the smell of the burn. After heavy burns have occurred on his right hand, he could not work anymore.

Based on the scenario given above, the students were expected to discover what the problem is and what may be the source of this problem. The students did various research in the classroom for their modelling study (reflex model) from the source books and the internet, and tried to obtain information about the neuron connection patterns and the direction of the impulse transmission. In this stage, the students expressed that the problem Mr. Ferhat experienced was failure of neural conduction.

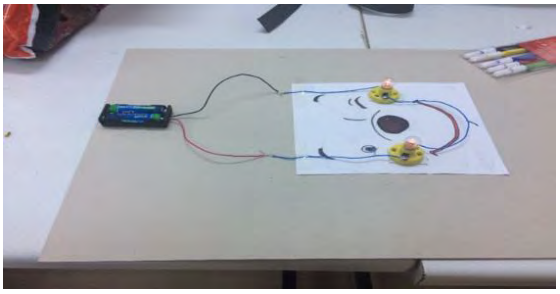
The groups were asked to design a model that can show Mr. Ferhat's situation. The group members brainstormed different ideas in order for their newly-designed models to work properly. Each group tried to create the best models using the tools in the supply pool and they made revisions when the model did not work. The groups were told to write on their worksheets the materials that they used during the model design process and the strategy that they followed. At the end of the design process, each group presented a simulation of their model to the other groups. They explained how their model represents the reflex action and what problem Mr. Ferhat possibly experienced.

The models that were created by the students are as follows:

1. The modelling of the pull-back reflex when we touch a hot object (Photographs 1 and 2).
2. The modelling of the laughter reflex (Photograph 3).
3. The modelling of the reflex that may occur in an emotional situation (e.g., a blush) (Photographs 4 and 5).
4. The modelling of knee-jerk reflex (Photographs 6 and 7).

Photograph 1. Students Prepare Their Model for the Pull-back Reflex

Photograph 2. The Model for the Pull-back Reflex



Photograph 3. The Model for the Laughter Reflex

Photograph 4. Students Prepare Their Model for the Reflex that may Occur in an Emotional Situation

Photograph 5. The Model for the Reflex that may Occur in an Emotional Situation

Photograph 6. Students Prepare Their Model for Knee-jerk Reflex

Photograph 7. The Model for Knee-jerk Reflex

As an example, the model for the pull-back reflex in Photograph 2 is explained here. The group explained their modeling process as follows. “We planned our model. We took the decisions collectively. We selected the materials. And then we created our model.” The students designed a model that showed the pull-back reflex in case of a sudden situation. In their model, they preferred to use cardboard, colored cardboard, glue, battery, salt water solution, wire, bulb, and 1.5-volt motor. In this model, the students carried out stimulation by touching the conductive wire to the batteries, considering that neural conduction should be initiated in their models. The water in the plate shown in Photograph 2 represents hot water. They used the saline solution as synapse and caused the light bulb on the hand to burn and the motor to move the hand.

Explanation

The students presented the models that they created to their friends in classroom environment. With the guidance of their teachers during the presentation, they explained the neurons that form the reflex arc and their functions.

A reflex is a quick unchanging response to sudden external stimuli. In a reflex arc, sensory neurons, associated neurons, and motor neurons might exist. However, a reflex may also take place in the presence of sensory and motor neurons. The sensory neuron transmits the external stimulus to the motor neuron as an impulse. The associated neurons in the spinal cord, which is the reflex center, evaluates the impulse, and then, sends it to the motor neuron. The motor neurons enable the transmission of the response to the related muscles or glands. Moreover, the teacher made various

explanations about the functions of the spinal cord, reflexes, and the neurons that take place in the reflex arc. The teacher also explained the concepts related to the topic.

Elaboration

In this stage, the students were asked to provide examples of daily life practices about reflexes with the help of the model they have designed. They were required to do research on the practices such as local anesthesia and botox as well as stroke, to find out due to the destruction of which neurons these situations arise, and to show this on the model they have designed (Appendix 1). The groups investigated the connections between neurons and these practices. The following response illustrates a typical answer. One group wrote "Local anesthesia- failure of sensory neuron. Botox- failure of sensory neuron. Stroke- failure of both sensory and motor neurons."

The students were also asked to do research on some possible solutions that can be used for the treatment of loss of reflex. Some solutions offered by the students involved "Heat sensitive gloves might be produced.", "Sensory neurons can be renewed by stem cell study.", and "Heat sensing receptors can be renewed by the stem cell method." Student used their models to show how these solutions can be applied in a reflex arc.

Evaluation

The criteria used in the evaluation of the students' designs are the types of neurons that the students have planned to include in the reflex arc, the types of connections between neurons, and the direction of the pathway for the impulse. Furthermore, each group presented their own design and design procedure and simulated the model in the class, which was evaluated by the other groups. "Product (Design) Evaluation Rubric" (Gülhan, 2016, p. 97) was used for evaluation of the activity. While evaluating according to rubric, the criteria such as suitability for purpose, originality, and functionality have been taken into consideration. In the end, the model for the pull-back reflex was selected as the best model with 20 points in class.

Finally, the last section, titled "What I Have Learned?" of the KWL table, which was filled out by the students in the introduction step of the 5E learning model, was completed. The students expressed that they learned about brain, spinal cord, neurons, the reflex action, types of reflex, and reflex arc. For example, one group wrote "We learned how reflex takes place and the role of brain in the reflex action." Another group wrote "We learned the elements of the reflex arc, innate reflex, conditional reflex, and instinct."

CONCLUSIONS and SUGGESTIONS

Within the scope of the current study, in order to achieve the outcomes regarding reflexes, the reflex arc and the functions of the neurons that form the reflex arc by using the 5E learning model, the students were engaged in completing a STEM activity. They shared their satisfaction with their teachers during and after the lesson. Due to this aspect of the activity, it is thought that the activity had a positive effect on the students. Moreover, the students stated that they had the opportunity to conduct a scientific study and felt that they could improve their designing skills in this way since they did research, questioned, asked questions and discussed the solutions and shared their ideas in classroom environment with active participation.

In the introduction stage of the activity and especially since the moment they started to think about the suggestions for a solution regarding a problem set, the students had spent an effort to base their hypotheses that they had formulated and the basic knowledge necessary to create their models on scientific data and scientific knowledge. They thought that they had to determine the type of neurons depending on their functions and to establish the connections among these neurons properly in order to create a reflex arc model because enabling the transmission of the impulse from sensory neurons to associated neurons or the transmission of the response, which was formed after the evaluation in associated neurons, to related muscles or glands through motor neurons was essential for the model to work. In this respect, it is thought that the STEM activity which was conducted for the current study is also necessary for the students to learn the concepts and the relationships between them. In addition, based upon the research findings of the

studies in the related literature on students' efforts such as trying alternative neuron connections while designing and simulating their models and forming new junctions using the data they gathered during the STEM activity if the model did not work, it is thought that the activity might be effective in the development of scientific process skills (Gokbayrak & Karisan, 2017).

The STEM activity that the students did within the scope of this study is about nerves, and homeostasis, which are covered in biology lessons, and the context in the activity was created with the help of engineering, mathematics, and technology disciplines. For example, it is thought that since the students have used engineering and designing skills while they were creating the model for the reflex arc (choosing the appropriate supplies for the design, and designing, drawing and implementing the connections between the neurons depending on the direction of the impulse, revising the model when it did not work), this will probably form a ground for various studies that the students would conduct especially in the field of applied engineering. The students used their technical knowledge on the working principals of the model when they drew the model they had designed. When its connection to technology is considered, the students used various supplies (e.g., battery holder, conductive wires in different diameters, electric motor, and motion-sensitive sensors) during the modelling process of the reflex arc. Then, they presented the model they had designed using the smart board and computers in classroom environment. At the same time, they made several mathematical comments (ratio, proportion) in order to form the connections between the neurons and to enable the transmission of an impulse from one neuron to the other in their models. For the functionality and visuality of the model, they had a chance to use various reasoning skills. In this respect, it is thought that the activity would be a good suggestion for biology teachers and would be beneficial for the teachers and the students.

It is believed that the activity developed in the current study would set an example for other activities to be used in other lesson topics of biology or in other disciplines. In addition, with the supplies that were chosen for the activity and used by the students with ease or with other alternative supplies, similar or different activities might be planned.

While implementing the activity, it is essential for the teacher to act as a guide and to direct the students when they need. The teachers need to prepare their lesson plans very carefully, determine the supplies to be used in the activity and provide the students with them, and form the time schedule. Moreover, the teachers should have the necessary information about the methods and techniques (e.g., 5E learning model, problem solving, project-based learning) used in the STEM activity and provide solutions to the possible problems that they might face in the classroom.

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Appendix 1

Student Worksheet

Section I

1. Is it possible for the response that the toy baby has given to take place in our bodies?

2. How do you respond when you are exposed to a loud noise or a sudden action? What might the reasons for your responses be?

3. Write the reasons for the incidents that took place in the cartoon you have watched.

Section II

Answer the questions below about the problem set you are given.

"Mister Ferhat works as a chef at the school cafeteria. One day, he had a traffic accident when coming back home from work. After the treatment period, he returned to his job. However, although he holds hot objects with his right hand all the time, he never feels pain. He realizes the burns on his hand only after he feels the smell of the burn. After heavy burns have occurred on his right hand, he could not work anymore."

1. What might be the reason for the situation that Mister Ferhat experienced after the accident?

2. Design a model that can show Mister Ferhat's situation.

3. Write the tools and materials you used in the design of your model and why you needed them.

4. Please write the steps you followed in the design process.

Section III

1. Show which neurons are damaged as a result of local anesthesia and botox practices as well as stroke in your model.

2. Write suggestions for a solution to Mister Ferhat's situation.

Section IV

Complete the KWL table below

What I Know	What I Want to Know	What I Have Learned