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Teaching the Relationship between Metabolic Rate and O_2 Consumption of Animals with Fixed/Variable Body Temperature by Use of the Predict-Observe-Explain (POE) Strategy[1]

Sabit ve Değişken Vücut Sıcaklığına Sahip Olan Hayvanlarda O_2 Miktarı ile Metabolizma Hızı Arasındaki İlişkinin Tahmin-Gözlem-Açıklama (TGA) Yöntemiyle Öğretimi

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Abstract

This study aims to teach the relationship between metabolic rate and oxygen consumption to pre-service science teachers by using the POE strategy. Among the qualitative research methods, the case study design was used. The study sample consisted of 32 pre-service science teachers from a university's faculty of education department of science education, who took the course "General Biology Laboratory". A work sheet titled "Oxygen Consumption of Animals" prepared based on the Predict-Observe-Explain (POE) strategy was used for data collection. The data was analyzed using frequencies (f) and percentages (%). At the end of the study, 95.3% of the participants were found to be actively involved in the prediction step. It was also found that all of the participants made observations and expressed their reasons, while 98.5% participated in the explanation step. These findings reveal that pre-service science teachers tend to be actively involved in all steps when such kind of teaching strategy is presented to them.

Keywords: Metabolic rate, Oxygen amount, POE strategy, Pre-service science teachers.

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Öz

Bu çalışmada, fen bilgisi öğretmen adaylarına, kullanılan oksijen miktarıyla metabolizma hızı arasındaki ilişkinin, TGA yöntemiyle öğretimi amaçlanmıştır. Nitel araştırma yöntemlerinden, durum çalışması deseninin uygulandığı çalışmaya; 2014-2015 eğitim-öğretim yılının bahar döneminde bir üniversitenin eğitim fakültesinin fen bilgisi öğretmenliği anabilim dalında öğrenim gören ve "Genel Biyoloji Laboratuvarı" dersini alan 32 öğretmen adayı katılmıştır. Araştırmada, veri toplama aracı olarak "Hayvanlarda Oksijen Tüketimi" başlıklı TGA yöntemine göre düzenlenmiş bir çalışma yaprağı kullanılmıştır. Verilerin analizinde, frekans (f) ve yüzde (%) dağılımlarından yararlanılmıştır. Sonuç olarak öğretmen adaylarının %95,3'ünün tahminde bulunarak sürece etkin biçimde katıldığı, tamamının gözlem yaparak gözlemlerine gerekçe yazdıkları ve %98,5' inin de açıklama aşamasına katıldığı tespit edilmiştir. Bu sonuçlardan hareketle öğretmen adaylarının, bu tür bir öğretim yaklaşımının öne çıkarılması halinde, tüm aşamalara etkin biçimde katılma eğiliminde oldukları anlaşılmaktadır.

Anahtar sözcükler: Metabolizma hızı, Oksijen miktarı, TGA yöntemi, Fen bilgisi öğretmen adayları

Atıf:

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Introduction

Laboratory activities have long been seen as important components of science courses (Bennett, 2000; Boud, Dunn, & Hegarty-Hazel, 1986; Johnstone & Al-Shuaili, 2001; Psillos & Niedderer, 2002). Deters (2005) found that they are often the most popular element of courses and they have also been shown to stimulate and motivate students to learn more about science (Hofstein & Lunetta, 2004). Laboratory learning is a cornerstone of most science degrees because it provides students with an opportunity to develop and practice the skills needed to become scientists (Barrie, Bucat, Buntine, Silva, Crips et al., 2015).

In Turkey the 2013 science curriculum (3, 4, 5, 6, 7 and 8th grades) attaches particular importance to the use of laboratories. Laboratory instruction in science teaching has been reported to promote active student participation, help students acquire new information about topics they curious about by means of personal observations, encourage them to participate in researchers that involve their opinions and efforts and help them establish relationships among different concepts, learn ways of accessing scientific facts, use theoretical information in their everyday lives, gain concrete learning experiences and develop positive attitudes toward science course (Ayvacı & Küçük, 2005; Hanif, Sneddon, Al-Ahmadi & Reid, 2009; Lee, Lai, Yu, & Lin, 2012; Osbourne, Simon, & Collins, 2003; Ottander & Grelsson, 2006; Secker & Lissitz, 1999). Besides, laboratory instruction is also expected to help students establish meaningful relationships between theoretical knowledge and the observations they made during the laboratory activities, thus making laboratories real learning environments. The main purpose of practical teaching activities—especially of biology laboratory courses—should be to increase meaningful learning, to ensure active participation of students in the knowledge structuring process, to give students the responsibility of their learning and to encourage them.

Some of the studies reported that students experience some difficulties during laboratory activities and laboratory activities fall short of helping students understand the relationship between laboratory observations and theoretical knowledge; therefore laboratories are far from providing a meaningful learning environment (Friedler & Tamir, 1990; Johnstone & Al-Shuaili, 2001; Nakhleh & Krajcik, 1993; Rice, Thomas & O'Toole, 2009). This may be attributed to the failure in constructing the learning method employed in laboratory activities properly or implementing it as proposed. Another challenge is the inapplicability of some experiments, in which the Predict-Observe-Explain (POE) strategy will be used, for making observation. At this point, it is of high importance to know the topics that are suitable for employing the POE strategy, to know which method will increase student success more and to make a selection accordingly. All these show that the conventional teacher-centered teaching methods are not sufficient and the Science Curriculum should be restructured based on a teaching theory that will help achieving its objectives.

The POE method was firstly arranged as demonstrate-observe-explain (DOE) by Champagne et al. in 1979 and was administered by them to explore the thinking skills of the first grade students receiving physics education at Pittsburgh University. Then it was transformed into predict-observe-explain (POE) by Gunstone and White (1981) (Quoted in Yıldırım & Maşeroğlu, 2016).

As part of the three-step POE strategy which is based on the constructivist approach, materials required for the laboratory experiment should be provided beforehand, and students should be provided with information about the experiment. It is especially important that students must express their predictions in their own sentences. During this step, the most important thing to remember is to record the predictions before the observation step. In the following step, students should perform their experiments and observe the process at the same time. After the experiment, their observations should be written down. In the explanation step, students should be asked to compare their predictions and observations, and if there is any discrepancy, explain the reasons. Explanation is the most important step that show whether students understand the event, or not. However, students' prior knowledge and their familiarity with such kind of instruction also have an effect on the implementation of this strategy.

POE can be described as a more constructive strategy than other concept teaching strategies. Helping students relate the new knowledge to their existing knowledge and express their knowledge in a meaningful way, this strategy is especially applicable for science courses. (Cengiz, 2018; Dalziel, 2010; Hilario, 2015; Kibirige, Osodo & Tlala, 2014; Köklükaya & Güven Yıldırım 2018; Sesen, 2013;Tereci, Karamustafaoğlu & Sontay, 2018; Tiftikçi, Yüksel, Koç & Sert Çıbık, 2017).

There is a fewer number of studies on teaching O_2 consumption of animals and its relationship with metabolic rate compared to the other subjects in biology. Studies suggest that teachers convey only some basic information about this subject, which causes students to perceive it as an abstract topic. It is also indicated that activities to attract the attention of students must be carried out while teaching respiration together with effective applications (Börner, 2004; Dudley, 1973; Piercy et al., 2015; Yaman, 2009).

It is striking that studies on teaching respiration are mostly in the field of health sciences (Koçkar et al., 2016; Kömür et al., 2016; Nemli & Demiral, 2016; Önemli & Çatal, 2016), and biochemistry (Prothero, 1979; Reiss, 1987; Woodhead & Reiss, 1991, and references therein).

The studies conducted in the field of educational sciences are related to photosynthesis, respiration and respiratory system (Akçay, 2016; Bilen & Aydoğdu, 2010; Çetin, 2013; Çokadar, 2012; Dikmenli Vardar, 2015; Keleş & Kefeli, 2010; Mann & Treagust, 1998; Métioui, Matoussi & Trudel, 2015; Ross, Tronson & Ritchie, 2006; Sander, 1993; Songer & Mintzes, 1994; Töman, Çimer & Çimer, 2015; Yürük & Çakır, 2000). Yaman (2009) examined the contexts and methods that attract the attention of students and found that, among eight different contexts of respiration and energy acquisition, the interest was at its highest level within the context of health. From this finding, it can be concluded that relating the topic to health while teaching respiration and employing different teaching methods instead of conventional ones increase students' attention and have an indirect but positive impact on their success.

This study aims to teach the relationship between metabolic rate and oxygen consumption to pre-service science teachers by using the POE strategy. We believe that experimental activities will help pre-service science teachers change their perspectives towards everyday facts, events and problems, and develop positive attitudes to learning science concepts and using scientific methods during the problem solving processes. We also believe that this process will have positive impacts on the achievement of meaningful learning if it is planned in a way to help pre-service science teachers see the relationship between science concepts and daily life.

This study is significant because there is a lack of research covering teaching the relationship between metabolic rate and oxygen consumption of an organism to pre-service science teachers, who are to educate elementary school students, through the POE strategy. Also, the study is considered to be contributing to enhancing the knowledge of future science teachers that is pre-service teachers, about this strategy and its implementation steps and to their scientific explanations concerning the relationship metabolic rate and oxygen consumption of an organism.

Method

Case study design which is a holistic qualitative research method that aims to analyze one or several cases holistically within their own limitations was used in this study. The holistic single-case design may involve a single unit of analysis such as an individual, an institution, a program or a school as well as addressing the issues that have not been studied before (Kaplan-Öztuna, 2013; Yıldırım & Şimşek, 2008).

Study Group

The study group consisted of 32 second-grade pre-service science teachers studying at a university's faculty of education department of science education in the spring semester of the 2014-2015 academic year. 78% of the participants (25) were female and 22% (7) were male.

Data Collection Tools

In this study, a work sheet titled "Oxygen Consumption of Animals" which was prepared by the researchers based on the Predict-Observe-Explain (POE) strategy was used for data collection. The work sheet was prepared based on the Elementary Science Education curriculum of the Faculty of Education and the learning outcomes for the topic of respiration defined in the 2013 Biology Curriculum for Secondary Grades (Milli Eğitim Bakanlığı [MEB], 2013).

The work sheet had three sections, i.e. prediction, observation and explanation, each having open-ended questions. The prediction step included questions such as "What kind of change do you expect after these subsequent steps? Write down your predictions with your reasons", the observation step included questions such as "Please write down your observations" and the explanation step included questions such as "Compare your predictions with your observations. If your predictions do not match your observations, write your explanations for the discrepancy." The opinions of one biology professor and two science education experts were taken in order to check the content validity of the worksheet and determine whether or not the questions in the worksheet were clear, understandable, and suitable in terms of face validity and whether or not they contained any statement whose power of representing the studied subject and content validity had to be increased or which was unnecessary or unclear and had to be corrected.

Implementation

Before the experiment, the pre-service science teachers were informed about the process and the features of the POE strategy. They were also provided with a detailed work sheet (Annex 1) which included the steps of prediction, observation and explanation regarding the setup and the experiment, and three different teaching materials which included detailed information about the implementation of the experiment and the related biological topics and concepts such as the metabolic rate of an organism, the amount of oxygen consumed by organisms and the reasons for selecting rabbit and frog for this experiment.

The pre-service science teachers were asked to establish the experimental setup and then fill in the sections reserved for the steps of prediction, observation and explanation in the work sheet in line with the information provided to them. For the prediction step, they were asked to write down their predictions before the experiment with their reasons. In the observation step, they were asked to conduct the experiment and record their observations. Finally, in the explanation step, they were asked to explain, with reasons, whether their predictions matched their observations. They were free to write the reasons for their predictions, observations and explanations. Throughout the whole process, all experiments, student behaviors, predictions, observation, in-class discussions and explanations were recorded by the researchers in written and visual form (video, camera) to be analyzed later. The pre-service science teachers were provided with the opportunity to manage the process on their own and were offered guidance when they needed.

Activity: Oxygen consumption of animals. The amount of oxygen consumed by an organism is directly proportional to its metabolic rate. Metabolic rate can be measured by measuring the amount of oxygen consumed within a certain period of time. This activity which lasted a week aimed to measure and compare the oxygen consumption rates of a rabbit and a frog (Annex 2). The steps of the experiment are given below:

1- Design the experimental setup as shown in Figure 1.

2- After weighing the rabbit, place it in the setup as described in the figure. Follow the same steps for the frog.

3- Pay attention to seal the jar with an absolutely air tight lid.

4- Put a drop of colored liquid to the glass tube.

5- Try to find the direction of the colored liquid using the following equation:

$CO_2 + [Ca(OH)_2]_s \rightarrow CaCO_3 + H_2O$ (It was assumed that all CO_2 generated during respiration reacted with $Ca(OH)_2$, there was no free CO_2 gas discharge, and $CaCO_3$ did not cause any CO_2 emission due to heat or any other reason).

6- Measure and record the distance that the colored liquid has travelled at certain intervals (This time used for measurement will depend on the oxygen consumption rate of the animal). After each measurement, open the lid to provide the animal with fresh air.

Calculate the amounts of oxygen consumed by the rabbit and frog in millilitres. Use a syringe to do this. Mark the location of the plunger and push it all the way to move the colored liquid. Measure the amount using the scales. This amount measured in millilitres corresponds to the amount of oxygen consumed by the animal.

7- Put some ice cubes and hot water in plastic bags around the jar to measure and compare the oxygen consumption rates of the rabbit and frog at different temperatures.

8- To compare the oxygen consumption rates of the animals, present the findings for the rabbit and frog using a chart.

9- Calculate, in millilitres, the average amount of oxygen per 100 grams of bodyweight of each animal per hour using the following equation.

Example: Animal's weight: 250 gr
Amount of oxygen per 3 min: 6 ml
Amount of oxygen 100 grams of bodyweight: 2 ml/ 2.5= 0.8 ml
(1 ml = 1000 mm)

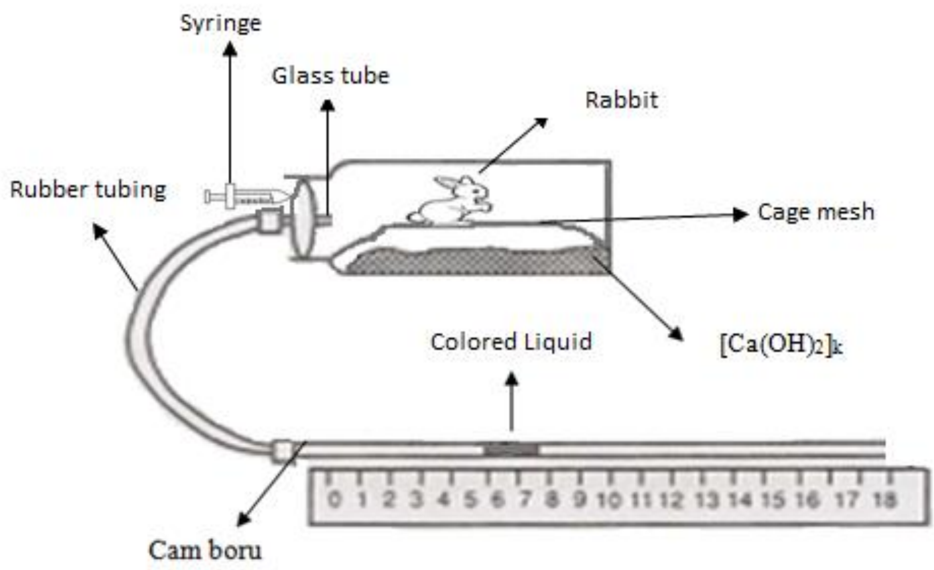

Figure 1: **An Experimental Setup to Measure Oxygen Consumption** (Milli Eğitim, Gençlik ve Spor Bakanlığı, [MEGSB], 1986).

Data Analysis

As the first step of data analysis, work sheets of the participants were numbered from 1 to 32. The answers given in the predict and explain stages were evaluated and categorized. Frequency (f) and percentage (%) values were taken into consideration during data analysis. Table 1 shows the categories related to the predict stage and the explain stage and the contents of these categories.

Table 1. The Categories Used in Analyzing the Questions Included in the Predict and Explain Stages and Their Contents

Stage	Category	Content
Predict	Correct prediction	An answer that contains all aspects of the valid answer.
	Partly correct prediction	An answer that contains one aspect of the valid answer, but not all aspects.
	Incorrect prediction	Irrelevant or unclear answer; no answer; answer like “I do not know”, “I do not understand”.
Explain	Prediction and observation are consistent.	Expectation is consistent with what is observable during the experiment or the activity.
	Prediction and observation are partly consistent.	Expectation is partly consistent with what is observable during the experiment or the activity.
	Prediction and observation are inconsistent.	Expectation is inconsistent with what is observable during the experiment or the activity.
	No answer	-

Evaluation in the POE Method

The learning process of the person during the creation of knowledge is important in the POE method, and assessment and evaluation are included in the learning process. The learning process of the student is evaluated rather than the outcome. POE activities are learning activities as well (Piburn & Baker, 1997). Ruiz-Primo and Furtak (2004) graded the accuracy of the predictions as well as the accuracy and meaningfulness of the explanations related to the predictions while grading the POE worksheets (http://www.cse.ucla.edu/products/reports/r639.pdf, 2016). However, it is not appropriate to grade answers at any stage of the POE method. That is because this method is also a learning tool. As the aim is to reveal the existing knowledge of the student in the prediction stage, students may avoid writing their predictions if they are graded (Gunstone & White, 1992). It is not appropriate to grade the observation stage either as students tend to write what they are supposed to see rather than what they actually see during the implementation (Atasoy, 2004). No extra implementation is carried out in POE in order to determine a scaled level of learning. As the deductive learning approach maintains its effect throughout the process, the preservice teachers themselves perform a non-scaled self-assessment before, after, and during the implementation. They can be inspected without compromising the integrity of the POE. If it is certain that grading will be performed, the rationality and accuracy of the information on which the students base their predictions and explanations at the end of the experiment can be graded. As POE-based activities aim to contribute to learning theoretical foundations of experiments or facts in a more meaningful manner, grading must be rather within the scope of formative evaluation.

Validity and Reliability

A science teacher and a faculty member from the biology department were asked to assess the data collection tool. They provided a positive opinion. In this way, we ensured the validity of the work sheet. In the work sheet, we created a separate line for each response for the purpose of ensuring that a response is not affected by the previous responses, thus maintaining reliability at a high level. To test the reliability, the data was grouped separately by two researchers and the percent of agreement was found to be 82.9%. A percent of agreement over 70% is considered acceptable (Miles & Huberman, 1994). Moreover, participants’ direct quotations from the prediction and explanation sections were used.

Findings

This section presents the frequencies and percentages of the responses given in the prediction, observation and explanation steps as well as the predictions and explanations. Table 2 shows that predictions of all pre-service science teachers about the first question were correct. They all stated that the rabbit consumes more oxygen than the frog. 71.9% of the pre-service science teachers correctly predicted the direction of the colored liquid in the glass tube, while 28.1% predicted wrong. Those who made wrong predictions stated that $Ca(OH)_2$ reacted CO_2 and prevented the liquid from moving.

About the relationship between body weight and oxygen consumption, 78.1% of the made correct predictions and 9.4% made partially correct predictions, while 12.5% made wrong predictions. The preservice teachers who partly made the right prediction accurately predicted that there was a correlation between the body weight and the amount of consumed oxygen but stated that the correlation was inverse, not linear. It was found out that the preservice teachers who made inaccurate predictions stated that the correlation between the body weight and the amount of consumed oxygen was related to the lung volume (Table 2).

About the relationship between oxygen consumption and placement of ice cubes and hot water around the jar, 15.6% of the pre-service science teachers made correct predictions and 40.6% made partially correct predictions, while 25% made wrong predictions. It was also found that 18.8% of the participants left the question unanswered. Those who made partially correct predictions indicated that the metabolic rates of both animals would increase as the temperature increased, or vice versa. On the other hand, those who made wrong predictions stated that temperature changes were not related to oxygen consumption (Table 2).

About the consistence between the predictions and observations about the first question, 56.3% of the pre-service science teachers made correct explanations and 12.5% made partially correct explanations, while 31.3% made wrong explanations. Those who made partially correct explanations associated the oxygen consumption of the frog and rabbit to their body weights (Table 2).

About the consistence between the predictions and observations about the second question, 65.6% of the pre-service science teachers made correct explanations and 21.9% made partially correct explanations, while 12.5% made wrong explanations (Table 2). Those who made partially correct explanations stated, "*Rabbit consumes more oxygen, because frog lives in wetlands. I think this reduces the amount of oxygen consumed by the rabbit. It might also be related to the rabbit's bodyweight.*"

About the consistence between the predictions and observations about the third question, 59.4% of the pre-service science teachers made correct explanations and 34.4% made partially correct explanations, while 6.3% made wrong explanations. Those who made partially correct explanations stated, "*There is a relationship, because we can see that people who are overweight get out of breath, while underweight people move more easily.*", while those who made wrong explanations indicated that oxygen consumption was not related to bodyweight, but to lung volumes instead.

Table 2. Pre-service Science Teachers' Predictions and Explanations about the Activity Titled "Oxygen Consum

Questions and Answers		Prediction (N=32)			
		Correct		Partially Correct	
		f	%	f	%
Question 1	Which one consumes more oxygen: a rabbit or a frog? Write down your predictions with your reasons.	32	100	-	-
Expected Answer	*Warm-blooded (endothermic) vertebrates such as birds and mammals have high metabolic rates. Therefore, their oxygen consumption rate is high. The amount of energy consumed by such organisms in their daily life can only be compensated by fast metabolism. Warm-blooded vertebrates need a specific metabolic and O_2 consumption rate to maintain a specific body temperature. Therefore, rabbits consume more oxygen than frogs.*				
Question 2	Which direction does the colored liquid in the glass tube move? Write down your predictions with your reasons.	23	71.9	-	-
Expected Answer	*Carbon dioxide produced by the animal reacts with $[Ca(OH)_2]_s$. As the animal uses oxygen, air pressure drops in the left side of the liquid and the high external pressure causes the liquid to move towards the jar.*				
Question 3	Is there any relationship between bodyweight and the amount of oxygen consumed during a set period of time? Write down your predictions with your reasons.	25	78.1	3	9.4
Expected Answer	*Body weight is directly proportional to the oxygen consumption rate. Measurement of the amount of oxygen consumed by an organism within a set period of time gives its metabolic rate.*				
Question 4	What kind of change do you expect when you place a plastic bag of ice cubes or hot water around the jar and compare the oxygen consumptions of the animals at different temperatures? Write down your predictions with your reasons.	5	15.6	13	40.6
Expected Answer	*When the ambient temperature rises, the metabolic rate increases in ectothermic animals (frog) and decreases in endothermic animals (rabbit). Therefore, the frog consumes more oxygen than the rabbit if we place hot water around the jar. On the other hand, the rabbit consumes more oxygen than the frog if we place ice cubes around the jar.*				

About the consistence between the predictions and observations about the fourth question, 50% of the pre-service science teachers made correct explanations and 28.1% made partially correct explanations, while 15.6% made wrong explanations. 6.3% were found to leave the question unanswered (Table 2). Those who made wrong explanations stated, "*If we place a hot water bottle, the ambient air humidity increases, thus making breathing difficult.*"

Below are some of the opinions of the pre-service science teachers who made correct predictions and explanations about this activity.

A3: The colored liquid in the glass tube moves toward the jar, because there is a CO_2 retainer in the jar.

A11: The liquid moves towards the left, because the animal needs to use the oxygen in the jar. Therefore, the pressure inside the jar drops and the liquid moves towards the inside of the setup.

A14: I think bodyweight is directly proportional to oxygen consumption.

A28: As the bodyweight and energy consumption of the rabbit is high, it consumes more oxygen.

A31: When we place a hot water bottle, the frog consumes more oxygen, because it needs to balance its body temperature and ambient temperature.

A32: Rabbit breathes slowly in hot water and rapidly in cold water, because hot weather slows down metabolism, while cold weather boosts it.

Table 3. Pre-service Science Teachers' Answers about the Oxygen Consumption of Animals

Observations of the pre-service science teachers	f	%
The colored liquid in the glass tube moved toward the left in both setups.	28	87.5
The rabbit was breathing more rapidly than the frog.	21	65.6
When a bag of ice cubes was placed on the rabbit's jar, it began to move and sniff around.	8	25
When a hot water bottle was placed on the rabbit's jar, it seemed as if it was about to drowse off to sleep.	5	15.6
When a hot water bottle was placed on the frog's jar, it started jumping.	3	9.4
When a bag of ice cubes was placed on the frog's jar, it stopped jumping.	2	6.3

87.5% of the pre-service science teachers stated that the colored liquid in the glass tube moved toward the left in both setups. 65.6% indicated that the rabbit began to breathe more rapidly. 25% of the pre-service science teachers stated that the rabbit began to move rapidly, while 15.6% stated that the rabbit's movement slowed down when a hot water bottle was placed on its jar. 9.4% indicated that the frog began to move rapidly when a hot water bottle was placed on its jar, while 6.3% stated that its movements slowed down when a bag of ice cubes was placed on the jars (Table 3).

Discussion and Conclusion

In this study aiming to teach the relationship between metabolic rate and oxygen consumption to pre-service science teachers by using the POE strategy, we found that all of the pre-service science teachers made correct predictions about whether the rabbit or the frog would consume a larger amount of oxygen per unit of time. However, most of them were found to relate the difference in the oxygen consumptions of these two animals to their body weight instead of different metabolic rates of endothermic and ectothermic animals. 71.9% of the pre-service science teachers correctly predicted the direction of the colored liquid in the glass tube. Besides, 78.1% made correct predictions about the relationship between body weight and oxygen consumption (Table 2).

It is remarkable to see that the ratio of correct predictions about the changing metabolic rates of animals depending on the ambient temperature was very low (15.6%). The explanations they made about their reasons show that they only focused on the body sizes of two animals and failed to relate the issue with endothermic and ectothermic animals. Variations in the metabolic rate of organisms with body size and temperature have long been known, with the classic work in this field being that of Hemmingsen (1950; 1960). Gillooly, Charnov, West, Savage, and Brown (2002), Clarke (2004) and Piercy et al (2015) were found that different temperature values are the effect of living organism on metabolic rate. Given the changing respiratory rates of plants at different temperatures, we believe that the abovementioned issue has been to a great extent overlooked during the teaching of biology (Hoyt & Wallenstein, 2011).

The increase in the ratio of explanation observed in the step of explaining the consistence between the predictions and observations, compared to the ratio of correct and partially correct predictions, showed that making observations after the prediction step was effective in clearing up the misunderstandings of pre-service science teachers and helping them achieve permanent learning.

Studies analyzed the responses given by the pre-service science teachers in the prediction step and found that they brought their own prior knowledge that is different from scientifically accepted concepts and based on different experiences, ideas and beliefs they gained on their own about science concepts, thus they had various misconceptions. It was also found that they corrected such misconceptions to a considerable extent by making observations, thus observations after the prediction step were important in learning (Küçüközer, 2008; Liew & Treagust, 1995; Tatlı & Ayas, 2011).

The pre-service science teachers made the following observations about this activity: the rabbit was breathing more rapidly; the colored liquid in the glass tube moved toward the left in both setups, but the movement was much more in the setup with the rabbit; the rabbit's movement slowed down but the frog's movement increased when a hot water bottle was placed on the jars; the rabbit's movement increased but the frog's movement slowed down when a bag of ice cubes was placed on the jars (Table 3). At this step of the POE strategy, the pre-service science teachers were asked to record their observations both quantitatively and qualitatively using the open-ended questions, tables and charts. At the end of the study, the POE strategy was found to promote effective use of pre-service science teachers' science process skills and to emerge as a method that improve their skills of producing knowledge, thinking over a problem and structuring the results (Altınok, 2017; Chang et al., 2013; Kearney, 2002, 2004; Palmer, 1995; Treagust, Mthembu & Chandrasegaran, 2014). The findings also revealed that the POE strategy helped the students use their existing knowledge and experience to support their predictions based on similar situations they encounter in daily life. From these results, it would appear that the use of living animals in the lessons can have a positive influence on pupils' attitudes (Killermann, 1998). A further study dealt with the use of living animals in classroom lessons (Bauhardt, 1990).

As we know there is no study in the literature on the oxygen consumption of animals that involve the planned implementation of the POE strategy, we were not able to make a detailed comparison; however, we concluded that knowledge was used in the steps of prediction, observation and explanation consecutively. Therefore, the steps were linked to each other, making the strategy have a more formal and holistic structure. The study also revealed that pre-service science teachers tend to be actively involved in all steps when such kind of teaching strategy is presented to them.

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Geniş Özet

Giriş

Yapılandırmacı yaklaşımı temel alan yöntemlerden biri olan üç aşamalı TGA yönteminde, uygulamaya başlamadan önce laboratuvarda yapılacak deney ile ilgili gerekli malzemeler temin edilmeli ve öğrencilere deneyin yapılışı hakkında bilgi verilmelidir. Öğrencilerin, tahminleri ile bu tahminleri destekleyen nedenleri, ya açık uçlu ifadeler kullanarak ya da kendi cümlelerini yazarak belirtmeleri sağlanmalıdır. Özellikle öğrenciler tahminlerini, kendi özgün ifadeleriyle belirtmelidirler. Bu aşamada, dikkat edilmesi gereken en önemli nokta, tahminlerin, gözlem yapılmadan önce kayıt altına alınmasıdır. Sonraki aşamada, öğrenci deneyini yapmalı ve aynı zamanda süreci de gözlemlemelidir. Deney bittikten sonra gözlem sonuçları yazılmaya başlanmalıdır. Açıklama aşamasında, öğrencilerden tahminleri ile gözlemlerini karşılaştırmaları, şayet birbiriyle çelişen durum varsa, bunun nedenlerine ilişkin açıklama yapmaları istenmelidir. Öğrencilerin olayı anlayıp anlamadıklarını gösterecek olan en önemli aşama açıklama aşamasıdır. Ancak bu yöntemin uygulanmasında, öğrencilerin daha önce öğrenmiş olduklarının ve bu şekildeki bir çalışmaya ne kadar alışık olduklarının da etkisi vardır.

Çalışmada, fen bilgisi öğretmen adaylarına, kullanılan oksijen miktarıyla metabolizma hızı arasındaki ilişkinin, TGA yöntemiyle öğretimi amaçlanmıştır. Böylece deneysel etkinliklerle öğretmen adaylarının, günlük hayatlarında karşılaştıkları olgulara, olaylara veya problemlere bakış açılarının değişeceği, problem çözme sürecinde, fen derslerindeki kavramları öğrenme ve bilimsel yöntemi uygulamaya yönelik olumlu tutum geliştirecekleri düşünülmektedir. Bu sürecin, öğretmen adaylarının günlük yaşamlarıyla, fen kavramları arasındaki ilişkiyi görmelerini sağlayacak şekilde planlanması halinde anlamlı öğrenmenin gerçekleşmesine olumlu etkileri olacağı kanısındayız.

Yöntem

Çalışmada, nitel araştırma yöntemlerinden, bir veya birkaç durumu kendi sınırları içerisinde bütüncül olarak analiz etmeyi amaçlayan durum çalışması deseni kullanılmıştır. Araştırmanın çalışma grubu, 2014-2015 eğitim-öğretim yılının bahar döneminde bir üniversitenin eğitim fakültesinin fen bilgisi öğretmenliği 2. sınıfında öğrenim gören 32 öğretmen adayından oluşmaktadır. Öğretmen adaylarının 25'i (%78) kız, 7'si (%22) erkektir. Çalışmada veri toplama aracı olarak, araştırmacılar tarafından hazırlanan; "Hayvanlarda Oksijen Tüketimi" başlıklı TGA yöntemine göre düzenlenmiş bir çalışma yaprağı kullanılmıştır.

Verilerin analizi

Tahmin ve açıklama aşamalarında verilen cevaplar değerlendirilerek kategorilere ayrılmıştır. Verilerin analizinde, frekans (f) ve yüzde (%) dağılımlarından yararlanılmıştır. Çalışma yapraklarının tahmin ve açıklama aşamalarından elde edilen veriler "doğru", "kısmen doğru" ve "yanlış" şeklinde üç kategori altında değerlendirilerek analizi uygulanmış, herhangi bir puanlama yapılmamıştır.

Geçerlik ve güvenirlik

Veri toplama aracı bir fen eğitimcisi ve biyoloji öğretim üyesinin görüşüne sunulmuş ve olumlu görüş alınmıştır. Buna göre, çalışma yaprakları geçerliliğinin sağlandığı kanısına varılmıştır.

Güvenirliğin tespiti için veriler iki araştırmacı tarafından ayrı ayrı gruplandırılmış ve uyum yüzdesi %82,9 olarak hesaplanmıştır. Uzlaşma yüzdesinin %70 ve üstünde olması kabul edilebilir değer sayılmaktadır (Miles ve Huberman, 1994). Ayrıca tahmin ve açıklama aşamalarına ilişkin öğretmen adaylarından doğrudan alıntılara yer verilmiştir.

Tartışma ve Sonuç

Öğretmen adaylarının tamamının kurbağa ve tavşandan hangisinin birim zamanda daha çok oksijen tüketeceğine ilişkin doğru tahminde bulunduğu belirlenmiş, ancak büyük çoğunluğunun tahminlerine, sıcakkanlı ya da soğukkanlı hayvanlardaki metabolik hızların farklı olacağı kanısından çok, vücut büyüklüğüyle ilişki kurmaya çalıştıkları tespit edilmiştir.

Öğretmen adaylarının %71,9'unun cam borunun içindeki renkli sıvının hangi yöne doğru hareket edeceğine, %78,1'inin vücut ağırlığıyla belirli zaman aralıklarında tüketilen oksijen miktarı arasındaki ilişkiye yönelik doğru tahminde bulunduğu görülmüştür (Tablo 2).

Öğretmen adaylarının çevre sıcaklığına bağlı olarak hayvanların metabolizma hızlarına yönelik doğru tahminde bulunma yüzdelerinin çok düşük (%15,6) olduğu dikkat çekmiştir. Bu noktada öğretmen adaylarının, tahminlerinin nedenlerine ilişkin yapılan açıklamaları incelendiğinde, kurbağa ve tavşanın sadece vücut büyüklüğüne odaklandıkları, hayvanların sıcakkanlı ya da soğukkanlıların dâhil oldukları sınıflarla ilişki kuramadıkları tespit edilmiştir. Farklı sıcaklıkların bitkilerin solunum hızını bile etkiledikleri göz önüne alındığında bu durumun biyoloji öğretimi sırasında önemli ölçüde gözden kaçırılmış olduğu düşünülmektedir (Hoyt ve Wallenstein, 2011).

Bu etkinliğe yönelik tahmin ve gözlem sonuçları arasındaki uyumu açıklamada öğretmen adaylarının, doğru ve kısmen doğru tahmin yüzdesine karşılık açıklama yüzdesinde artış görülmesinin, tahminden sonra gözlem yapmanın öğretmen adaylarının yanlış anlamalarını düzeltmede ve kalıcı öğrenmede etkili olduğunu göstermektedir.

Öğretmen adaylarının, hayvanlarda oksijen tüketimine ilişkin yapılan bu etkinlikteki gözlem sonuçlarından; tavşanın daha hızlı soluk alıp verdiği, cam boru içindeki sıvının her iki hayvanda da sola doğru kaydığı, ancak bu kaymanın tavşanda daha fazla olduğu, kavanozun üstüne sıcak su kesesi koyunca tavşanın hareketlerinin yavaşladığı, kurbağanın ise hızlandığı, buz kesesi koyunca tavşanın hareketlerinin hızlandığı, kurbağanın hareketlerinin yavaşladığı tespit edilmiştir (Tablo 2). Bu etkinliğe dönük olarak TGA yönteminin bu aşamasında öğretmen adaylarından gözlemlerini açık uçlu sorular, tablo ve grafiklerle nitel ve nicel olarak kaydetmeleri sağlanmıştır. Sonuç olarak TGA'nın; öğretmen adaylarının bilimsel süreç becerilerinin etkin kullanımına imkân verdiği, bilgi oluşturmada, problem üzerinde düşünmede ve sonuçları yapılandırmadaki becerilerini geliştiren bir yöntem olarak öne çıktığı görülmektedir. Ayrıca ulaşılan sonuçlardan TGA yönteminin, öğrenciye mevcut bilgisini ve deneyimlerini günlük hayatta karşılaştığı benzer olaylardan yararlanıp bunları tahminlerini desteklemek için kullanmasını sağladığı belirlenmiştir. Uygulamada, öğretmen adaylarının, bu tür bir öğretim yaklaşımının öne çıkarılması halinde, tüm aşamalara etkin biçimde katılma eğiliminde oldukları tespit edilmiştir.

Annex 1: Work Sheet

Name-Surname of the Student:
Number:
PREDICT-OBSERVE-EXPLAIN
Name of the Activity: Oxygen Consumption of Vertebrates

a. Prediction Step

1- Which one consumes more oxygen: a rabbit or a frog? Write down your predictions with your reasons.
………
2- Which direction does the colored liquid in the glass tube move? Write down your predictions with your reasons.
………
3- Is there any relationship between bodyweight and the amount of oxygen consumed during a set period of time? Write down your predictions with your reasons.
………
4- What kind of change do you expect when you place a plastic bag of ice cubes or hot water around the jar and compare the oxygen consumptions of the animals at different temperatures? Write down your predictions with your reasons. ……….

b. Observation Step

1- To compare the oxygen consumption rates of these two animals, write down your findings for each animal in the table below and show them on a chart.

Period (min)	Oxygen Consumption of the Rabbit	Oxygen Consumption of the Frog

2- Which one consumed more oxygen: the rabbit or the frog? Write down your observations.
………
……….
3- Calculate the average amount of oxygen per 100 grams of bodyweight of each animal per hour in millilitres.
………
……….

c. Explanation Step

1- Compare your predictions with your observations. If your predictions do not match your observations, write your explanations for the discrepancy.
………
……
2- How do you explain the movement of the colored liquid in the glass tube?
………
………
3- Which one is necessary to find the metabolic rate of an animal best: The total amount of oxygen used within a certain period of time or the ratio of the amount of oxygen consumed within a certain period of time to the animal's bodyweight? Please explain.
………
………
4- Try to make inferences about various factors that may affect the metabolic rates of different organism based on your findings and the figures given in Table 1.

Table 1: Oxygen consumptions of different animal per (1 ml = 1000 mm)

Animal	Oxygen Amount (mm^3)
Sea anemone	13
Sea worm	30
Octopus	80
Human	200
Squid	320
Hummingbird (still)	3500
Hummingbird (flying)	40000

Annex 2: Certificate

ULUDAĞ ÜNİVERSİTESİ 1975

DENEY HAYVANI KULLANIM SERTİFİKASI

Sertifika No: **2007 / 220**

Muhlis ÖZKAN

Uludağ Üniversitesi Hayvan Deneyleri Yerel Etik Kurulu tarafından ilgili yönetmelik hükümlerine göre deneyime dayalı olarak yetkin olması nedeni ile bu sertifikayı almaya hak kazanmıştır.

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