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Developing Sample Activity Based on Prediction- Observation- Explanation (POE) Teaching Method Supported by Concept Cartoons in Science Teaching Laboratory Applications

Emine YURTYAPAN[1] & Nezahat KANDEMİR[2]

Abstract

This study aims to introduce sample activities based on the Prediction-Observation-Explanation (POE) teaching method supported by concept cartoons developed for the teaching of biology subjects within the scope of science teaching laboratory applications-II course and to explain how the application is made. While developing the activities, the document analysis method, one of the qualitative research designs, was used. The implementation of the developed activities was carried out with 37 prospective science teachers who took the science teaching laboratory applications-II course at a state university. As a result of the study, sample activities based on the Prediction-Observation-Explanation (POE) teaching method were developed for the teaching of biology subjects within the scope of science teaching laboratory applications course-II. While developing activities based on the POE teaching method, concept cartoons can be used to provide discussion and motivation. In addition, students can reach different results in POE teaching practices. Within the framework of the constructivist learning approach, teachers can use the scaffolding techniques (question-answer, topic summaries, flow charts, etc.), both verbally and in activities, to eliminate such conflicting situations.

Key Words: *POE teaching method, Concept cartoon, Science teaching laboratory applications-II, Biology topics, Developing sample activity.*

Introduction

As in many global sociological events in the past, the Covid-19 pandemic process we are in has once again shown the importance of the race in science and technology to the whole world. In this challenging process and race, it is an inevitable fact that the most important need of our country is trained manpower. Therefore, prospective science teachers, who are responsible for raising future generations, should be equipped both in terms of subject area knowledge and in terms of applying teaching methods and techniques. In terms of gaining these qualifications, it

[1] Milli Eğitim Bakanlığı, Orcid ID: 0000-0003-4630-8601 / E-mail: emineyurtyapan@hotmail.com.
[2] Amasya University, Faculty of Education, Department of Mathematics and Science, Amasya, Turkey, Orcid ID: 0000-0002-5428-4139 / E-mail: nezahatkndmr@gmail.com.

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can be said that one of the most important courses in the undergraduate education of science teaching is science teaching laboratory applications I-II. When the science teaching laboratory applications I-II course content in the teacher training undergraduate program of the Council of Higher Education (CoHE, 2018) is examined, it is seen that it is aimed to gain the prospective teachers the ability to design experiments with simple tools for the teaching of middle school science course subjects by using different laboratory approaches. In this respect, it is considered important to show prospective teachers different laboratory approaches and exemplary teaching practices based on the constructivist learning approach within the scope of the science teaching laboratory applications course.

Since science teaching laboratory applications course is related to middle school science subjects in terms of content, it should be developed within the framework of constructivist learning approach to be able to use sample teaching practices to be shown to prospective teachers in the future. The constructivist learning approach, as in other laboratory approaches, draws attention to the importance of experimental activities in science teaching, as well as to gaining students the nature of science, scientific process, and life skills (Çelik, 2018). This integrative approach, which aims to teach science concepts together with these skills, is one of the features that distinguishes the constructivist learning approach from other laboratory approaches. The Ministry of National Education middle school science curriculum (MEB, 2005, 2013) aims to provide students with science literacy, the nature of science, scientific process, and life skills. However, traditional teacher-centered teaching methods such as lectures, note-taking, and verification-type laboratory activities are not effective in developing these skills of students (MEB, 2005). Since the objectives of the MEB (2005, 2013) and the characteristics of the constructivist laboratory approach are thought to be compatible with each other, in this study, sample activities based on the POE teaching method based on the constructivist learning approach were developed in the teaching of biology subjects within the scope of science teaching laboratory applications-II course.

Shiland's (1999) study titled "*Constructivism: The Implications for Laboratory Work*" draws attention to the importance of designing the constructivist laboratory environment within the framework of a student-centered understanding that will allow students to make predictions before experimenting and to discuss the results obtained from the experiment with their predictions. POE teaching method is based on the principle that students make observations after explaining their predictions about the subject to be learned and discover the contradiction between their predictions and observation results by questioning (Kearney & Treagust, 2001;

Köse, Coştu, & Keser, 2003; White & Gunstone, 1992). In this respect, it can be said that the student is the center and the teacher is the guide in the teaching process. Considering these features, it is thought that it is appropriate to develop the activities according to the POE teaching method within the framework of the constructivist learning approach. POE teaching method consists of three stages. These stages are:

Prediction Stage: At this stage, students can be given a demonstration experiment or a case study related to the subject to be taught (Laçin Şimşek, 2019). Various questions are asked for students to explain their predictions and reasons for the results of the given experiment and case study. Here, it is important to explain the reasons for their predictions and to reveal and feel the misconceptions in the preliminary information that make up the predictions.

Observation Stage: In the second stage, which is the observation stage, if a demonstration experiment is conducted during the prediction stage, it can be ensured that students do the same experiment at this stage. If a case study is used in the prediction stage, an experiment or activity for the target acquisition of the lesson can be made by students during the observation stage (Laçin Şimşek, 2019). During the observation stage, students can work individually or in groups.

Explanation Stage: In the explanation stage, which is the last stage, students are asked to explain if there are conflicting situations between their predictions and observations (Laçin Şimşek, 2019). For this, some techniques such as discussion, question, and answer can be used.

The most important feature of the POE teaching method is that it allows students to make predictions based on their prior knowledge and experiences (Köse et al., 2003). In this method, since the students will try to discover the new information they will learn through their prior knowledge, revealing and making the misconceptions of the students during the prediction stage will increase their curiosity and increase their motivation for the lesson and learning (Liew & Treagust, 1998; Tekin, 2008). Therefore, the prediction stage is the most important stage of the POE teaching method in terms of the efficiency of the other stages. When the studies on POE teaching practices are examined, it is seen that mostly traditional open-ended questions are used in the prediction stage (Akgün, Tokur, & Özkara, 2013; Baladın Duman, 2019; Bolat & Karamustafaoğlu, 2021; Köse et al., 2003). Context-based open-ended questions were used in the prediction stage of the activities developed within the scope of this study. Context-based questions are questions that are not routine in our daily life, but are encountered or can be

encountered, and require more reading and thinking (Kurnaz, 2013; Tekbıyık & Akdeniz, 2010). Considering the purposes of the prediction stage, such as identifying misconceptions and prior knowledge, attracting attention, and providing focus, it is thought that it would be more appropriate to use context-based open-ended questions at this stage. There are studies in the related literature showing that context-based questions give more positive results in terms of understanding, concreteness, and attracting attention than traditional questions (Park & Lee, 2004; Tekbıyık & Akdeniz, 2010). For this reason, context-based open-ended questions were used in the prediction stage of the activities. However, one of the effective techniques in identifying misconceptions is concept cartoons. In this study, in which activities based on the POE teaching method were developed, concept cartoons were used together with context-based open-ended questions in the prediction stage.

Concept cartoons are a concept learning and teaching technique developed by Brenda Keogh and Stuart Naylor in 1991 (Keogh & Naylor, 1999). These are cartoons with no humor purpose, in which the thoughts of two or more characters about the solution of a problem situation in daily life. The general purpose of using concept cartoons in teaching is to create a scientific discussion environment. For this reason, scientifically correct statements should be placed in the thought bubble of a character in the cartoon, and misconceptions should be included in the other thought bubbles. Kabapınar (2005) summarized the contribution of concept cartoons to the teaching process as follows:

- It enables to reveal the misconceptions in the current knowledge of the students.
- It allows students to discuss the reasons for their mistakes in the classroom environment.
- It ensures high participation in class discussions.

Since it is thought that the contribution of concept cartoons to teaching is suitable for the prediction stage, concept cartoons were used together with context-based open-ended questions in the prediction stage of this study, in which activities based on the POE teaching method were developed.

In the observation stage of this study, in which activities based on the concept cartoon supported POE teaching method were developed, experiments with simple and cheap equipment were included. In many studies on laboratory applications in science education in our country, it is stated that the reason for the inability to carry out laboratory studies effectively is the lack of tools, equipment, materials, and physical environment (Böyük, Demir, & Erol, 2010; Demir, Böyük, & Koç, 2011; Güneş, Şener, Topal Germi, & Can, 2013; Orbay, Özdoğan, Öner, Kara,

& Gümüş, 2003; Soğukpınar & Gündoğdu, 2020; Uluçınar, Cansaran, & Karaca, 2004). To eliminate this situation, it is thought that it is important to develop the ability of prospective teachers to design experiments with simple tools. Therefore, the experiments presented in the observation stage of this study, in which activities based on the POE teaching method were developed, can be an example for teachers, prospective teachers, and researchers. In the explanation stage, which is the last stage, the question-answer technique was used within the framework of the constructivist learning approach to compare the prediction and observation results.

When the literature is examined, there are many studies on the POE teaching method. (Akgün et al., 2013; Bilen & Aydoğdu, 2012; Bilen & Köse; 2012; Bilen, Köse,& Uşak, 2011; Öner Sünkür & Arıbaş, 2020; Tokur, 2011). However, it is seen that the studies in which sample activities related to POE teaching practices are presented are relatively less than other studies. (Ergül, Sarıtaş, & Özcan, 2020; Köse et al., 2003; Yıldırım & Maşeroğlu, 2020). In addition, it has been seen that most of the studies on POE teaching methods are for general laboratory (physics, chemistry, and biology) courses. (Ayvacı & Durmuş, 2016; Güngör, 2016; Karatekin & Öztürk, 2012; Kozcu Çakır, Güven & Özdemir, 2017). On the other hand, in the related literature, in a study carried out with biology teacher candidates by Güleşir, Aydemir, Kuş, Uzel, and Gül (2020), the POE teaching method was used in teaching physiology subjects within the scope of Special Teaching Methods-II course. Güleşir et al. (2020), as a result of the study, it was stated that the POE worksheets answered by the students during the teaching are an alternative assessment method to evaluate the teaching results. In this study carried out within the scope of science teaching laboratory applications-II course, it is thought that it is important for prospective teachers to see how they can be used by integrating concept cartoons with the POE teaching method. Therefore, this study aims to introduce sample activities based on the concept cartoon supported POE teaching method developed for the teaching of biology subjects within the scope of science teaching laboratory applications-II course and to explain how the application is made.

Method

While developing activities based on concept cartoon supported POE teaching method, document analysis method, one of the qualitative research designs, was used. Document analysis is a qualitative research method in which written and electronic documents are analyzed and interpreted to create empirical knowledge and understanding about a subject

(Corbin & Strauss, 2008). To create valid and reliable information with this method, it is necessary to systematically examine all documents related to the subject (Kıral, 2020). Therefore, in this study, national and international studies on concept cartoons and POE teaching practices were examined while the activities were being developed.

Research Process

The development process of the concept cartoon supported activities based on the POE teaching method is summarized below:

1. CoHE (2007) Science teaching laboratory applications-II course content examination and listing the seventh and eighth-grade biology topics in the MoNE (2013) middle school science curriculum.
2. Determining the middle school seventh and eighth-grade biology subjects that students have the most misconceptions and difficulties in understanding by scanning national and international literature.
3. Writing new metacognitive gains for prospective teachers based on the gains of the MoNE (2013) middle school science curriculum related to the determined middle school seventh and eighth-grade subjects and developing concept cartoon supported activities based on the POE teaching method for these gains.
4. After the activities are developed, the activities are finalized by making evaluations and necessary arrangements with two faculty members who teach science teaching laboratory applications-II.
5. Determining the third-grade prospective science teacher who will take the science teaching laboratory applications-II course for the implementation of the developed activities.
6. Creating a work plan for the implementation of the activities.
7. Implementation of the activities developed in the determined third-grade science teaching branch.
8. The activities were developed taking into account the course content of the CoHE (2007) teacher training undergraduate program and the MoNE (2013) middle school science curriculum. However, in 2018, the CoHE teacher training degree program and the MoNE middle school science curriculum were updated. For this reason, the suitability of the developed activities to the updated CoHE (2018) and MoNE (2018)

programs was examined by two faculty members teaching science teaching laboratory applications-II courses and a science education expert. It has been observed that there is no change in the science teaching laboratory applications-II course content, the number of lesson hours, the class level, and gains of determining topics. For this reason, no adjustments were made in the activities developed.

Implementation of Activities

The implementation of the concept cartoon-supported activities based on the POE teaching method was carried out with 37 prospective science teachers. Developed activities are related to biology subjects of science teaching laboratory applications-II course. During the teaching process of science teaching laboratory-II course in education faculties in our country, teacher candidates generally study in physics, chemistry, and biology laboratories for 4 weeks to experience the teaching practices of middle school physics, chemistry and biology subjects. For this reason, prospective teachers were divided into three groups. The implementation of the activities took 12 lesson hours (4 weeks) in each group. It was completed in 36-course hours (12 weeks) in total.

Findings

While developing concept cartoon-supported activities, the POE teaching method based on the constructivist learning approach was taken as a basis. The activities developed concept cartoon supported based on the POE teaching method are related to the biology topics of the science teaching laboratory applications-II course. According to CoHE (2007; 2018), in Science Teaching Laboratory Applications-II course, planning, conducting, and reporting experiments based on different laboratory approaches for the subjects in the middle school seventh and eighth-grade science curriculum; in experiments, approaches that can be applied in the evaluation of student performance should be adopted. Therefore, within the scope of this course, middle school seventh and eighth-grade biology topics in Table 1 were determined and concept cartoon-supported activities were developed based on the POE teaching method, which is frequently used in the teaching of laboratory courses.

Table 1. Middle School Seventh and Eighth-Grade Biology Topics Determined within the Scope of Science Teaching Laboratory Applications-II

Weeks	Topics	Number Of Activities
First Week	Sense Organs (Eye, Ear, Skin, Nose, Tongue)	5
Second Week	Acid Rain, Greenhouse Effect, DNA, Urinary System	4
Third Week	Photosynthesis, Blood Type Determination, Blood Pressure	3

Fourth Week	Substances Through the Cell Membrane, Cellular Respiration, Germination	3
TOTAL		**15**

A total of 15 concept cartoon-supported activities were developed for the biology subjects determined within the scope of science teaching laboratory applications-II course. MoNE (2013) middle school science curriculum and science teaching laboratory applications-II course are related in terms of content. For this reason, while developing concept cartoon-supported activities for the subjects in Table 1, the achievements in the MoNE (2013) science curriculum were taken into account. When the achievements in the MoNE (2013) science curriculum are examined, it is seen that they are related to metacognitive skills regardless of grade level. For this reason, while developing concept cartoon-supported activities, new metacognitive gains for prospective teachers were written based on the gains of middle school seventh and eighth-grade biology subjects in the MoNE (2013) science curriculum. However, in 2018, some updates were made to the CoHE teacher training undergraduate program and the MoNE middle school science curriculum. For this reason, the updated curriculums were re-examined and comparisons were made. When CoHE (2018) and CoHE (2013) teacher training programs were compared, it was determined that there was no change in terms of the purpose of science teaching laboratory applications-II, course content, and the number of the lesson hours. In addition, it was seen that the determined biology subjects were suitable for the MoNE (2018) middle school science curriculum in terms of grade level and gains. For this reason, no changes were made in terms of content in the activities developed based on the concept cartoon supported POE teaching method.

Concept cartoon-supported activities were applied to prospective teachers in the form of worksheets arranged according to the POE teaching method. Open-ended questions are generally used in the prediction stage of the courses conducted with the POE teaching method. However, in the prediction stage of the activities carried out in this study, concept cartoons were used together with context-based open-ended questions to reveal the pre-knowledge of prospective teachers and improve their prediction skills about problem situations. In addition, it is thought that the different ideas in the speech bubbles of the characters in the concept cartoons will support the scientific discussions that are desired to occur in the classroom environment. In the observation stage, there are experiments to be carried out by the prospective teachers in groups or individually to solve the problem situation in the concept cartoon. As a result of the experiment, the obtained data and results are discussed and compared by the

prospective teachers. Thus, within the framework of the constructivist learning approach, it is aimed that the prospective teachers reach generalizations for the solution of the problem situation that is the subject of the experiment and the concept cartoon. After the observation stage, there is the explanation stage. In the explanation stage, verbal questions are asked to the prospective teachers to compare the prediction and observation results. In this way, by creating an in-class discussion environment, the compatibility of the conflicting situations between the prediction and observation results of the prospective teachers and the thought that occurs throughout the class is checked for the target gain of the activity. If there is no consensus, the groups are asked scaffolding questions about how the experiment was conducted, what the data were and how they interpreted the data, allowing the prospective teachers to discover the sources of different ideas. Afterwards a worksheet with a visual-enriched subject summary and open-ended evaluation questions is distributed to the prospective teachers. In this section, the subject is summarized by the researcher who conducts the lesson, and which of the characters in the concept cartoon is telling the truth, along with the reason, briefly repeats the information discovered by the prospective teachers within the scope of the lesson. In the last stage, open-ended questions are included to evaluate the prospective teachers' ability to use the information they obtained from the activity in new problem situations related to the subject. Since the target gains of the activities are aimed at metacognitive skills, open-ended questions were preferred in the evaluation part to encourage prospective teachers to think more and to express their thoughts independently with their own words. The reason for including subject summaries enriched with various visuals in the worksheet at the explanation stage is to provide a scaffolding for prospective teachers to answer the evaluation questions on metacognitive skills given in this section.

Three of the activities developed within the scope of the study are presented in detail below as an example:

Activity 1

Part I: Formal Part

Subject: Sense Organs (Eye)

Duration: 25'

Student gain: Explains the process of receiving a warning and responding insight, respectively.

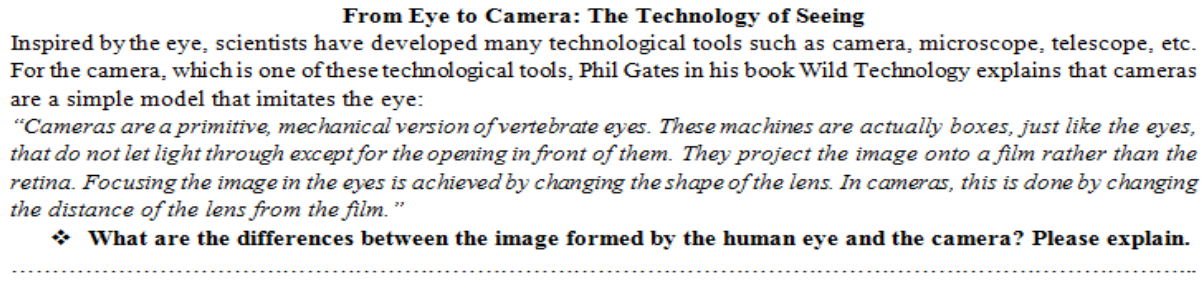
Teaching strategies, methods, and techniques: Constructivist teaching strategy, POE teaching method, question-answer technique, discussion, concept cartoon, experiment, brainstorming.

Instructional technologies, tools, and materials: Worksheets, fine-tipped spirit pen, ruler, round pieces of paper protruding from the punch hole.

Part II: Learning-teaching activities

Activity Name: Eye

Prediction Stage: In this section, prospective teachers are asked to answer the context-based open-ended question in Figure 1 and the concept cartoon in Figure 2 on the worksheet to draw their attention to the subject. The URL-1 internet resource was used while preparing the context-based open-ended question in figure 1.



From Eye to Camera: The Technology of Seeing

Inspired by the eye, scientists have developed many technological tools such as camera, microscope, telescope, etc. For the camera, which is one of these technological tools, Phil Gates in his book Wild Technology explains that cameras are a simple model that imitates the eye:

"Cameras are a primitive, mechanical version of vertebrate eyes. These machines are actually boxes, just like the eyes, that do not let light through except for the opening in front of them. They project the image onto a film rather than the retina. Focusing the image in the eyes is achieved by changing the shape of the lens. In cameras, this is done by changing the distance of the lens from the film."

❖ **What are the differences between the image formed by the human eye and the camera? Please explain.**

.....

Figure 1. A Context-Based Open-Ended Question at the Prediction Stage Prepared for the Sight (URL-1)

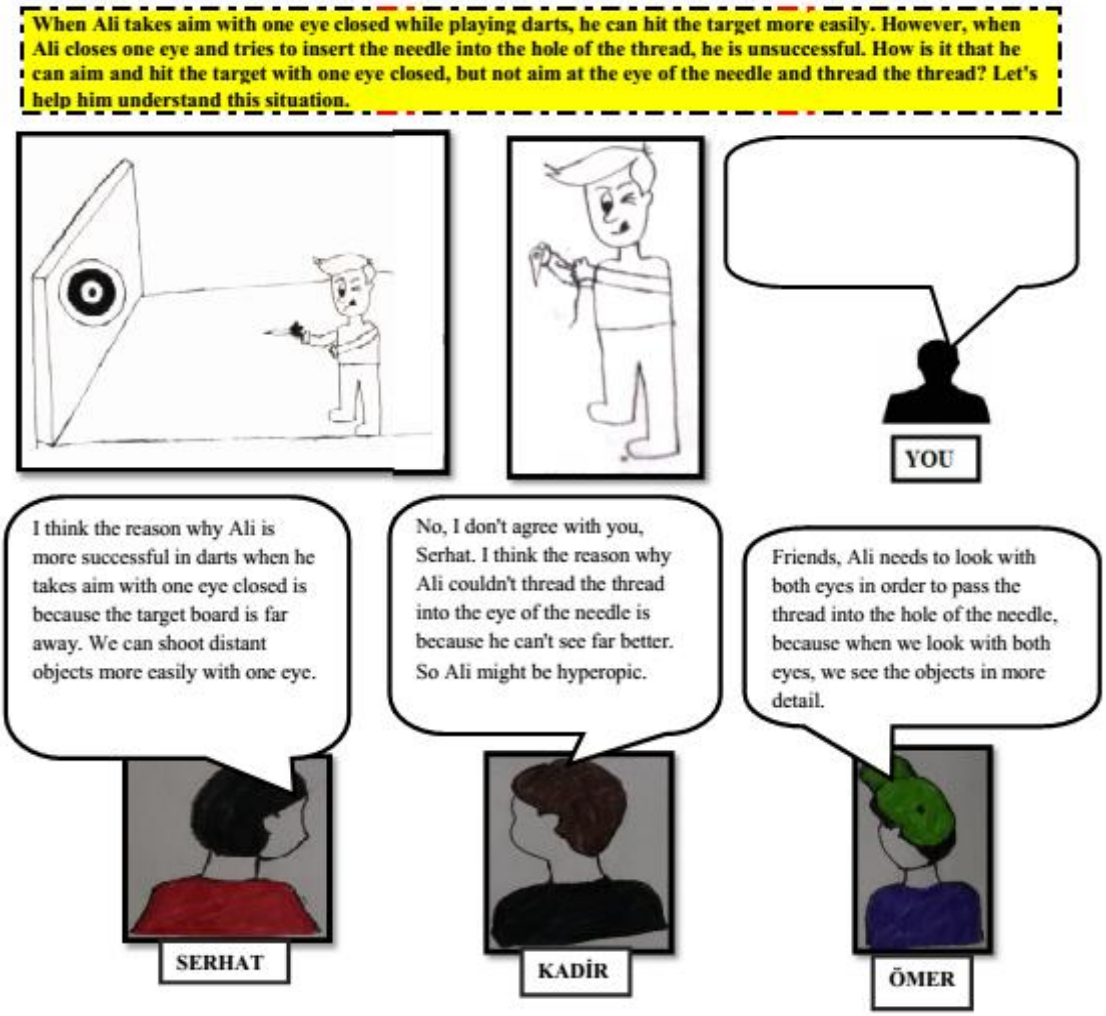


Figure 2. Concept Cartoon at the Prediction Stage Prepared for the Sight

After answering the question in Figure 1 and the concept cartoon in Figure 2, the volunteer prospective teachers are asked to share their predictions about the open-ended question and the problem situation in the concept cartoon, together with their reasons. While the expression in the speech bubble of the character "Ömer" in the concept cartoons is scientifically correct, the speech bubbles of the characters "Serhat" and "Kadir" contain misconceptions. On the other hand, the "you" character was placed so that if the opinions of the three characters in the concept cartoons were not found correct by the prospective teachers, they could write their [own] thoughts with their reasons. The purpose of sharing the answers they gave to the concept cartoon together with their reasons in the classroom environment is to ensure that the similar and different opinions in the reasons are compared and questioned by the prospective teachers. Therefore, the predictions and hypotheses made at this stage form the basis of the next stage. Thus, prospective teachers will have the opportunity to try different hypotheses in addition to their [own] hypothesis in the experiment at the observation stage.

Observation Stage:

To test the predictions and observations made, prospective teachers are asked to do the experiment given in Figure 3.

Tools to be used: Fine-tipped spirit pen, ruler, round pieces of paper protruding from the punch hole.

Purpose of Experiment: It is the ability of the subject to touch the piece of paper with the tip of the pen without pausing.

Experimental Procedure:

1. Work with a friend. One person will serve as the administrator of the experiment and the other person will serve as the test subject.
2. The test subject will kneel down so that their eyes are level with the surface of the table. (see figure below.)
3. The test subject will close one eye and try to touch the paper that the experiment manager has left on the table from a height of about 30 cm without pausing.
4. Measure the distance between the target (the piece of paper) and the point where the test subject touches the pencil. Note the result in the table below. The exact hit will be written as "0 cm".
5. Repeat the experiment 5 times. Calculate the average missed target with one eye.
6. Perform the experiment 5 more times, but this time with both eyes open. Write the data you have obtained in the table and calculate the average missed target rate.

Data:

	Missing rate (in mm)	
Experiment	**One Eye Open**	**Open in both eyes**
1		
2		
3		
4		
5		
Average		

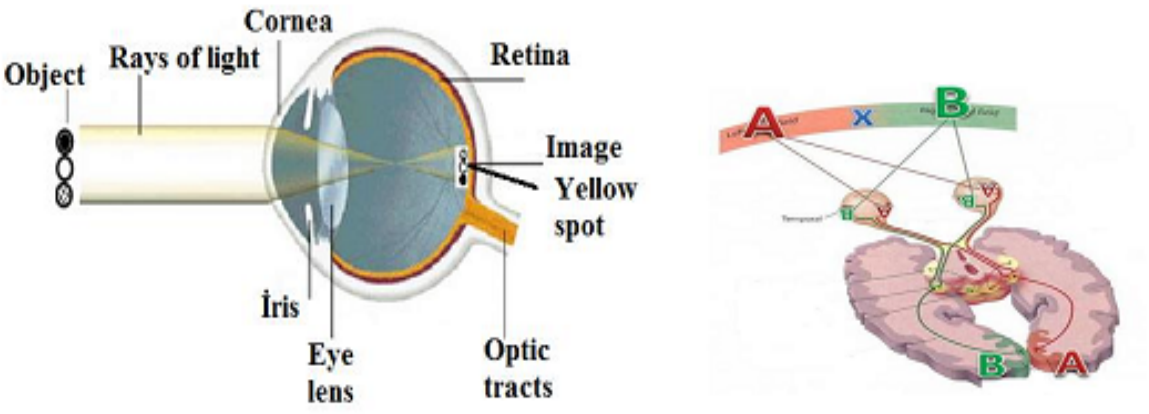
Figure 3. An Experiment Prepared for the Discovery of Sight

While performing the experiment given in Figure 3, prospective teachers should work as a group and divide the work to record the data on the worksheets. After the experiment, each group is asked to write down the analysis of the data they obtained and the results of the experiment on the worksheets. Thus, it is ensured that the ideas are shared, compared and the results of the experiment are decided within the group through in-group discussions.

Explanation Stage:

In the explanation phase, the researcher conducting the lesson poses questions to the groups to compare the predictions they made and the results obtained from the experiment. Thus, by providing a discussion environment between the groups, prospective teachers compare their

predictions, the data obtained from the experiment, and the results with each other. They can also evaluate their learning activity. In this section, some of the predictions made by the prospective teachers may have been falsified and some may have been confirmed. Then, a worksheet with a summary of the subject and evaluation questions enriched with visuals is distributed to the prospective teachers. The new information about the subject discovered by the prospective teachers as a result of their experiments and discussions is briefly summarized by the researcher who is conducting the course and it is repeated by explaining which character in the concept cartoon is telling the truth, along with the reason. To help the prospective teachers better understand the explanations and answer the question in the evaluation phase, a summary of the subject explaining how the seeing event took place and some visuals related to the subject were placed on the worksheet. These images and a summary of the subject are given in Figure 4. While preparing the images in Figure 4, URL-2 and URL-3 resources were used.



As seen in the figures above, while the image is formed in the eye, the rays reflected from the object pass through the following structures, respectively:

Cornea → Pupil → Eye Lens → Yellow Spot → Optic Tracts → Visual Cortex in the Brain (Macula) → Visual

These inverted images, which are formed separately in each eye, are combined and corrected in the visual cortex of the brain. Thus, the vision event takes place. Images formed separately in each eye are two-dimensional, like a photograph. But we see in three dimensions. This event occurs when two images formed in each eye are compared with each other in the brain. While our brain is combining two separate images, it also makes comparisons. Thanks to this comparison, our perception of depth is formed when we look at objects. Thus, we see our surroundings as three-dimensional, not two-dimensional like a photograph. There is a size difference between the two events mentioned in the cartoon above. In the first incident, while Ali is aiming at the target, the target, the dart that Ali will throw, and Ali's eye are on the same optical plane. Therefore, the event is one-dimensional. Therefore, we can hit the target using one eye while aiming. However, while Ali is trying to thread the thread into the hole of the needle, Ali's eye, the thread and the needle are not on the same plane. In order for Ali to do this job easily, he must perceive the depth between the thread and the needle. Therefore, he should look with both eyes.

Figure 4. Topic Summary Enriched with Visuals Describing the Visual Process (URL-2 &URL-3)

After the information in Figure 4 is repeated and the lesson is summarized, the activity is completed.

Part III: Measurement and evaluation

Since the target acquisition of the activity was aimed at metacognitive skills, questions were asked in the evaluation section to think and question how the vision event took place and the three-dimensional technologies produced by being inspired by the vision event. These questions are given in Figure 5.

1. **Based on the results of the experiment, give an example of the obstacles that can be caused by seeing with one eye.**

.....

2. If you were to design a camera that could take a three-dimensional photograph like the human eye, how would you design it?

.....

Figure 5. Evaluation Questions Prepared for the Visual Event

Activity 2

Part I: Formal Part

Subject: Greenhouse Effect

Duration: 30'

Student gain: It interprets the data in the graph about the greenhouse gases accumulating in the atmosphere and concludes.

Teaching strategies, methods, and techniques: Constructivist teaching strategy, POE teaching method, question-answer technique, discussion, concept cartoon, experiment, brainstorming.

Instructional technologies, tools and materials: Work Sheets, two plastic containers, aluminum foil, cling film, 2 thermometers, calcium carbonate, vinegar, 1 flask, 1 cork stopper, 1 glass pipe, 1 plastic pipe, 1 light bulb, and tape

Part II: Learning-teaching activities

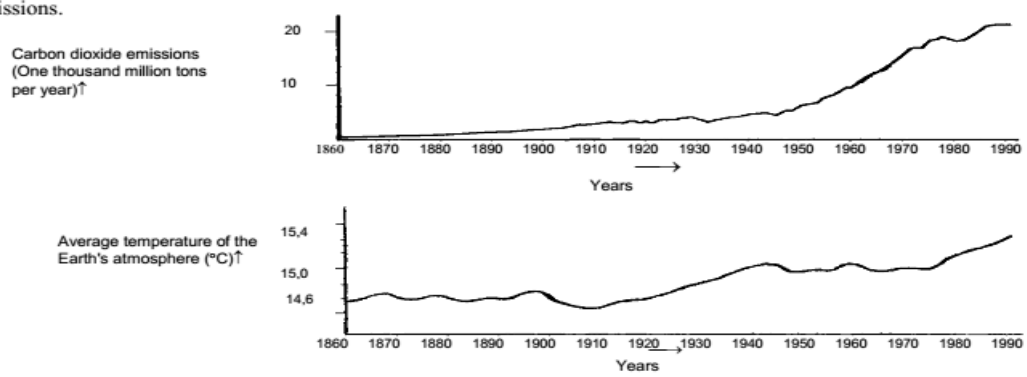
Activity Name: Greenhouse Effect

Prediction Stage: In this section, first of all, since the target achievement related to the subject is related to the interpretation of the data on the effect of greenhouse gases, the prospective teachers were asked to answer the context-based open-ended graphic question given in Figure 6 on the worksheet. The question in Figure 6 was inspired by the preliminary report prepared by MoNE (2010), which was prepared to evaluate the Program for International Student Assessment (PISA, 2009) exam results.

GREENHOUSE EFFECT: REAL OR IMAGINARY?

The energy that provides the continuation of life on earth comes from the sun, which spreads its energy to space because it is very hot. The earth's atmosphere creates a protective cover effect on our planet, preventing temperature changes that may occur in an airless environment. Most of the energy that comes from the sun in the form of rays passes through the earth's atmosphere. The earth absorbs some of this energy, and some is reflected back from the earth's surface. Some of this reflected energy is absorbed by the atmosphere. As a result, the average temperature above the earth's surface is higher than it would be in the absence of an atmosphere. The earth's atmosphere has the same effect as a greenhouse, so the term ***greenhouse effect*** is used. It is a fact that the average temperature of the earth's atmosphere increases. It is often said in newspapers and magazines that the increase in carbon dioxide emissions is the main source of the temperature rise in the twentieth century.

A student named Ali is interested in the possible relationship between the average temperature of the earth's atmosphere and the increase in carbon dioxide emissions on earth. He comes across the following two graphics in a book. **From these two graphs, Ali concludes:** It is certain that the increase in the average temperature of the earth's atmosphere is due to the increase in carbon dioxide emissions.



❖ **What supports Ali's conclusion in the graphics?**

……

❖ *Another student named Ceren disagrees with Ali's conclusion. She compares the two graphs and says that some parts of the graph do not support Ali's conclusion.*

Give an example of parts of the graphs that do not support Ali's conclusion. Explain your answer.

……

❖ *Ali insists on his conclusions that the increase in the average temperature of the Earth's atmosphere is due to the increase in carbon dioxide emissions. But Ceren thinks it's too early for her to come to a conclusion. Ceren says: "Before accepting this result, you should make sure that other factors that can cause the greenhouse effect are fixed."*

Indicate one of the factors that Ceren wants to say.

……

Figure 6. A Context-Based Open-Ended Question at the Prediction Stage for the Greenhouse Effect (MoNE, 2010)

Afterward, prospective teachers were asked to explain the concept cartoon in Figure 7, which was prepared to get their predictions for the experiment that could be designed to examine how the carbon dioxide gas, which is the subject of the graphic question, affects the greenhouse effect, together with the reasons, on the worksheets.

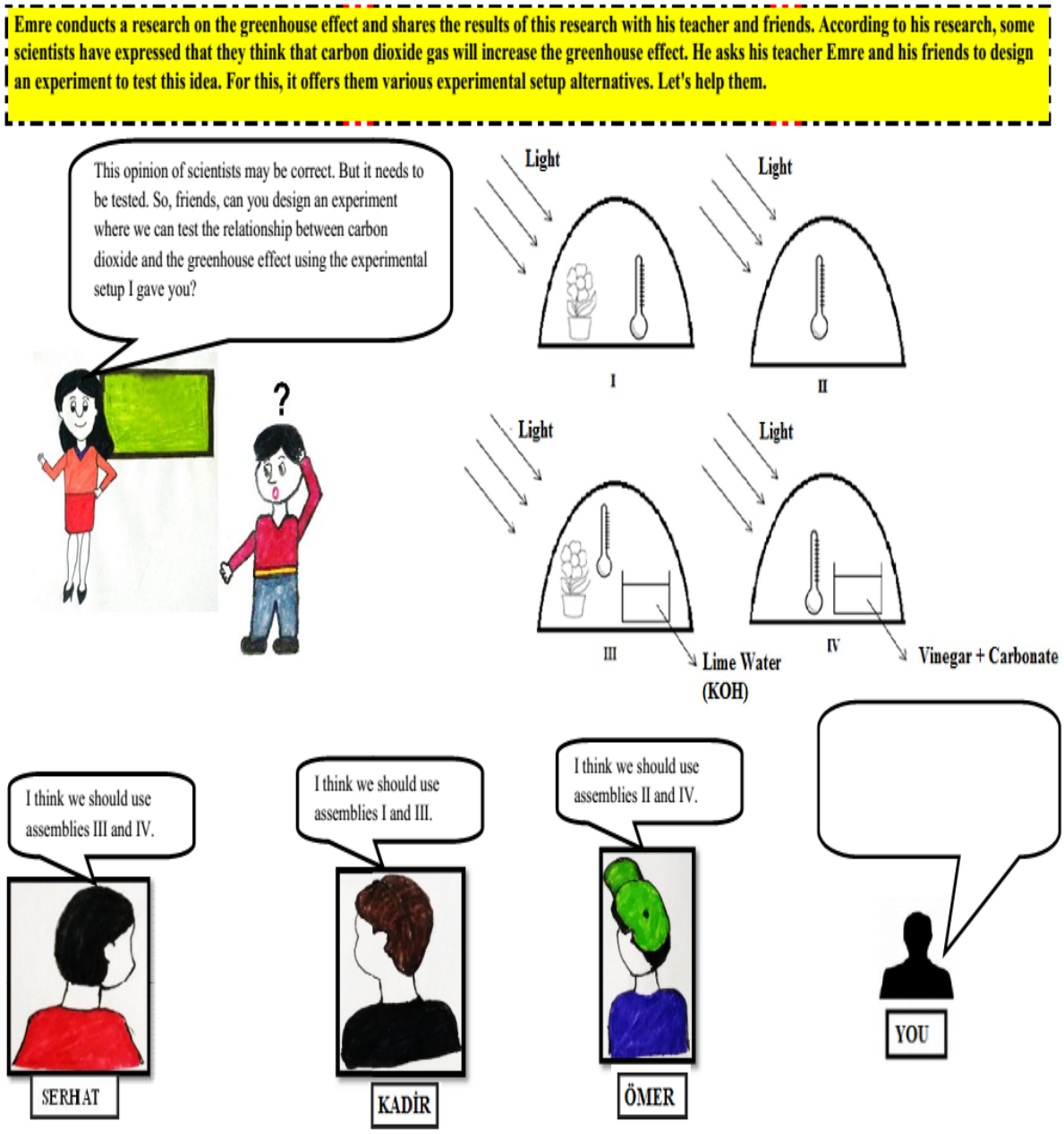


Figure 7. Concept Cartoon at the Prediction Stage for the Greenhouse Effect

After answering the question in Figure 6 and the concept cartoon in Figure 7, the volunteer prospective teachers are asked to share their predictions about the open-ended question and the problem situation in the concept cartoon, together with their reasons. While the expression in the speech bubble of the character "Ömer" in the concept cartoons is scientifically correct, the speech bubbles of the characters "Serhat" and "Kadir" contain misconceptions. On the other hand, the "you" character was placed so that if the opinions of the three characters in the concept cartoons were not found correct by the pre-service teachers, they could write their thoughts together with their reasons. The purpose of sharing the answers they gave to the concept cartoon

together with their reasons in the classroom environment is to ensure that the similar and different opinions in the reasons are compared and questioned by the prospective teachers. Therefore, the predictions and hypotheses made at this stage form the basis of the next stage. Thus, prospective teachers will have the opportunity to try different hypotheses in addition to their [own] hypothesis in the experiment at the observation stage.

Observation Stage:

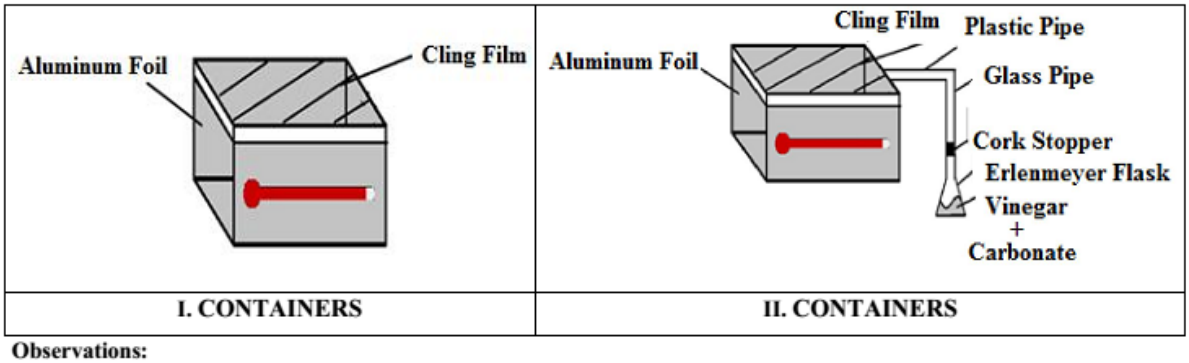
To test the predictions and observations made, the pre-service teachers are asked to do the experiment given in Figure 8.

Tools to be used: Two plastic containers, aluminum foil, cling film, 2 thermometers, calcium carbonate, vinegar, 1 flask, 1 cork stopper, 1 glass pipe, 1 plastic pipe, 1 light bulb and tape

Purpose of Experiment: To show the effect of carbon dioxide on the greenhouse effect.

Experimental Procedure:

1. Work in groups of 2-3 people.
2. Cover the inside of both plastic containers with aluminum foil.
3. Put the thermometer in its two containers.
4. Fix the pipe with tape so that one end of the plastic pipe is inside one of the containers.
5. Cover both containers with cling film in an airtight manner.
6. Put calcium carbonate and vinegar into the erlenmeyer flask. Close the mouth of the erlenmeyer flask with a cork stopper and connect the glass tube at the end of the cork to the plastic tube (see the figure below). Shake the erlenmeyer flask lightly.
7. Hold the light bulb from the top for about 10 minutes at an equal distance in both containers.
8. Record your observations during the experiment in the observations section below.



Observations:

	I. CONTAINERS	II. CONTAINERS
Initial temperature		
Temperature at the end of the experiment		

.....

Experiment Result:

Figure 8. The Experiment Prepared for the Discovery of the Greenhouse Effect

While performing the experiment given in Figure 8, prospective teachers should work as a group and divide the work to record the data on the worksheets. In addition, while doing this experiment, by creating different experimental groups, I. and III. By setting up the setup, they can make comparisons. After the experiment, each group is asked to write down the analysis of the data they obtained and the results of the experiment on the worksheets. Thus, it is ensured that the ideas are shared, compared and the results of the experiment are decided within the group through in-group discussions.

Explain Stage:

The explanation stage starts with the question-answer technique and the sharing of the predictions made by the groups and the results obtained from the experiment in the classroom environment. Thus, by providing an environment for discussion between the groups, the prospective teachers compare the data and results obtained from the experiment with each other. They can also evaluate their learning activity. In this section, some of the predictions made by the prospective teachers may have been falsified and some may have been confirmed. Then, a worksheet with a summary of the subject and evaluation questions enriched with visuals is distributed to the prospective teachers. The new information about the subject discovered by the prospective teachers as a result of their experiments and discussions is briefly summarized by the researcher who conducts the lesson, and which character in the concept cartoon is telling the truth is explained and repeated with its justification. To help the prospective teachers better understand the explanations and answer the question at the evaluation stage, a summary of the topic explaining how the greenhouse effect occurs and some related visuals are placed on the worksheet. These images and a summary of the subject are given in Figure 9. While preparing the image in Figure 9, the Greenhouse effect poster prepared by Bol (2013) within the scope of the "Instructional Technology and Material Development" course was used.

The earth is warmed by the rays reflected from the earth rather than the rays coming from the sun. These rays are held by gases in the atmosphere, including carbon dioxide, methane and water vapor in the atmosphere. Thus, the world warms. This effect of gases such as carbon dioxide, methane and water vapor in warming the world is called the greenhouse effect. In recent years, due to air pollution, greenhouse gases such as methane, ozone and chlorofluorocarbon (CFC) along with the amount of carbon dioxide have been increasing rapidly in the atmosphere as a result of various human activities. The increase in the amount of carbon dioxide and chlorofluorocarbons causes the temperature of the atmosphere to rise. This is called global warming. Scientists are worried that global warming will have serious consequences such as melting glaciers, climate change and rising ocean levels.

The contribution of various human activities to global warming is as follows:

1- Energy use 49%,

2- Industrialization 24%,

3- Deforestation 14%,

4- Agriculture is 13%.

In the experiment, the effect of carbon dioxide on the greenhouse effect was tried to be shown. The light source used in the experiment represents the sun. Covering the inside of the plastic container with aluminum foil represents the reflection of the rays from the earth. Covering the surface of the plastic container with stretch film represents the atmosphere of the world. The carbon dioxide released as a result of the mixing of calcium carbonate and vinegar in the erlenmeyer flask, it accumulates in the II. container. After 10 minutes, the value indicated by the thermometer in the II. container will be higher than the value indicated by the thermometer in the I. Container. Thus, the capacity of carbon dioxide to retain heat will be demonstrated.

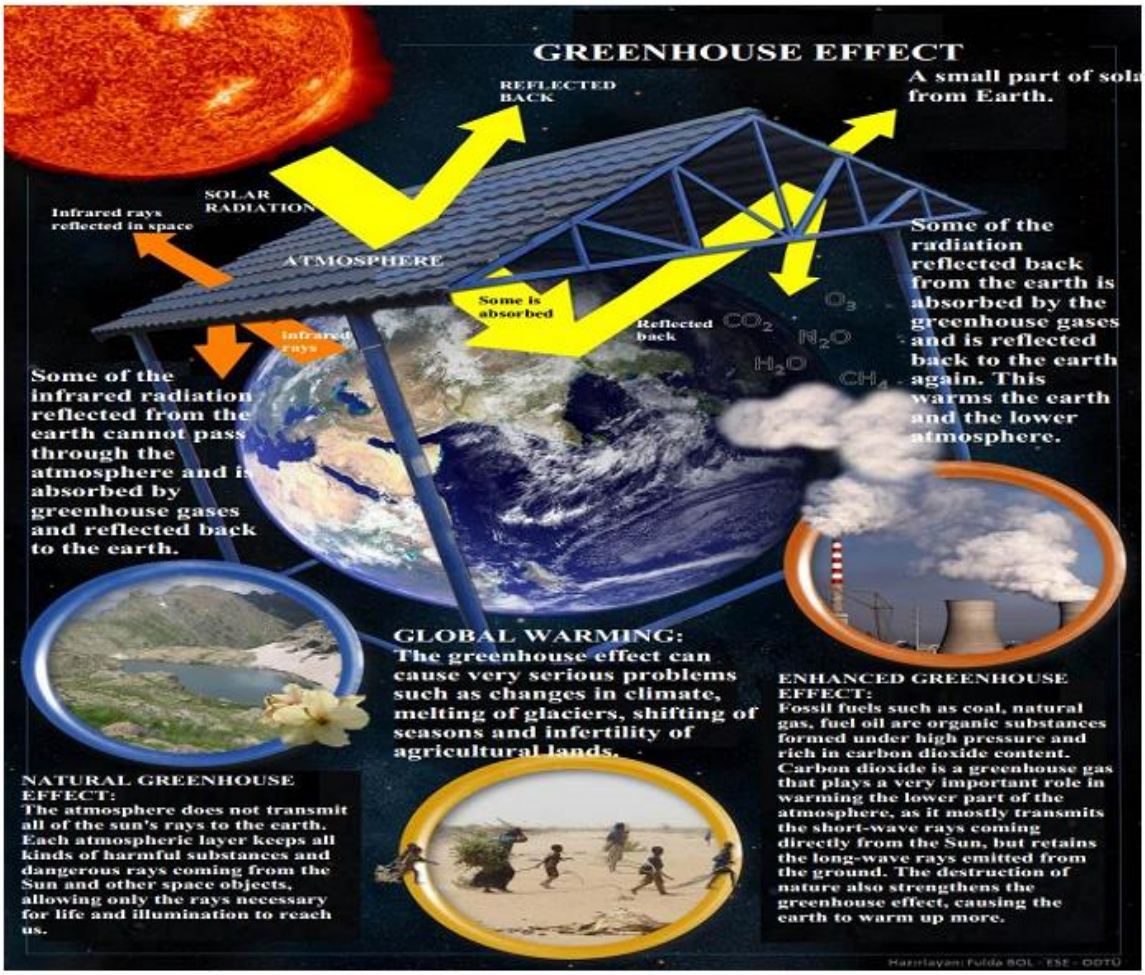


Figure 9. Subject Summary Enriched with Visuals Describing the Greenhouse Effect

(Bol, 2013)

After the information in Figure 9 is repeated and the lesson is summarized, the activity is completed.

Part III: Measurement and evaluation

Since the target acquisition of the activity is aimed at metacognitive skills, in the evaluation part, questions were asked to think and question how the greenhouse effect occurs and what its positive and negative effects might be on the world. These questions are given in Figure 10.

- **Do you think the greenhouse effect has benefits? If so, explain what.**

  .....
- **Carbon dioxide gas is the gas that causes the most greenhouse effect. Explain the reason for this?**

  .....
- **What are the sources of the gases that cause the greenhouse effect in the world? Could these gases be of natural origin? Please explain.**

  .....
- **What are the consequences of the greenhouse effect? Please explain.**

  .....

Figure 10. Evaluation Questions Prepared for the Greenhouse Effect

Activity 3

Part I: Formal Part

Subject: Structure of Deoxyribose Nucleic Acid (DNA)

Duration: 30'

Student gain: Examines the reason why small units (nucleotides) combine to form large units (nucleic acid) in the synthesis of nucleic acids.

Teaching strategies, methods, and techniques: Constructivist teaching strategy, POE teaching method, question-answer technique, discussion, concept cartoon, experiment, brainstorming.

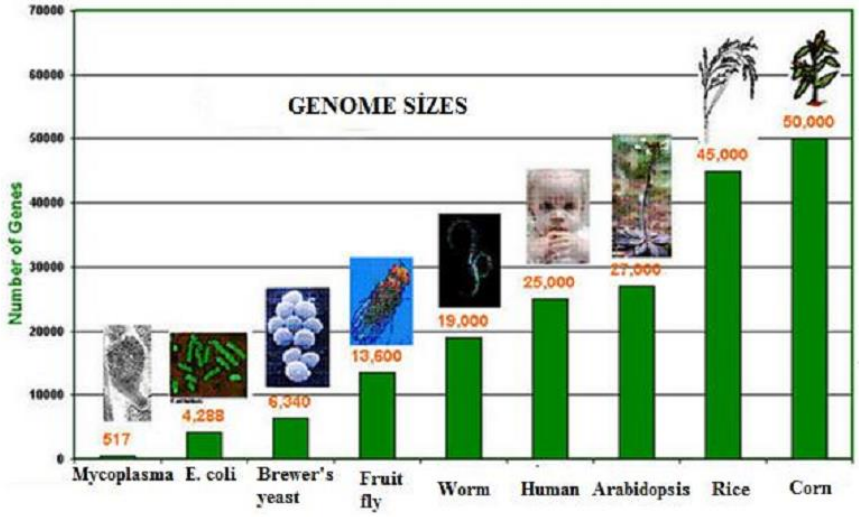
Instructional technologies, tools, and materials: Worksheets, one onion, grater or knife, a small bowl, one teaspoon of salt, hot water, liquid soap, filter paper, toothpick, alcohol (cologne), glass cup.

Part II: Learning-teaching activities

Activity Name: Structure of Deoxyribose Nucleic Acid (DNA)

Prediction Stage: When the target gain on the subject is examined, it is seen that it is aimed at understanding the relationship between the units of heredity (Chromosome, DNA, Gene, and Nucleotide). For this reason, prospective teachers were asked to answer the context-based open-ended question given in Figure 11 on the worksheet for the comparison of the gene number of living things in the prediction phase. While preparing the question in Figure 11, the visual prepared by Nevruzoğlu (2008) was used.

WHY ARE OUR GENE NUMBER SO LOW?



In **2001**, after the **draft genome sequence** was revealed, scientists came across a surprising result. Instead of the expected **100. 000** genes, only about **35.000-40.000genes** were discovered. Later, when **the project** was completed in **2003**, this number decreased even more. According to the latest research, the number of genes is estimated to be **20.000 - 25.000**. So, we know that humans have only **twice** as **many genes** as a **fly** and slightly more than a **mustard seed.**

As research continues and gene detection techniques advance, it is observed that this number is always decreasing. It is thought that the lower limit will stop at an estimated 10.000-odd.

Human	**Fruit Fly**
2.9 billion base pairs	120 million base pairs
25.000 genes	13.601 genes

❖ **The numbers of genes belonging to different living things are given in the graphic and table above. What conclusion would you draw by evaluating the data in this chart and table? Explain the reason.**

……

Figure 11. The Context-Based Open-Ended Question at the Prediction Stage about the Structure of DNA (Nevruzoğlu, 2008)

Then, they are asked to answer the concept cartoon in Figure 12 to the worksheets to get the prospective teachers' predictions about how the structure of DNA is studied.

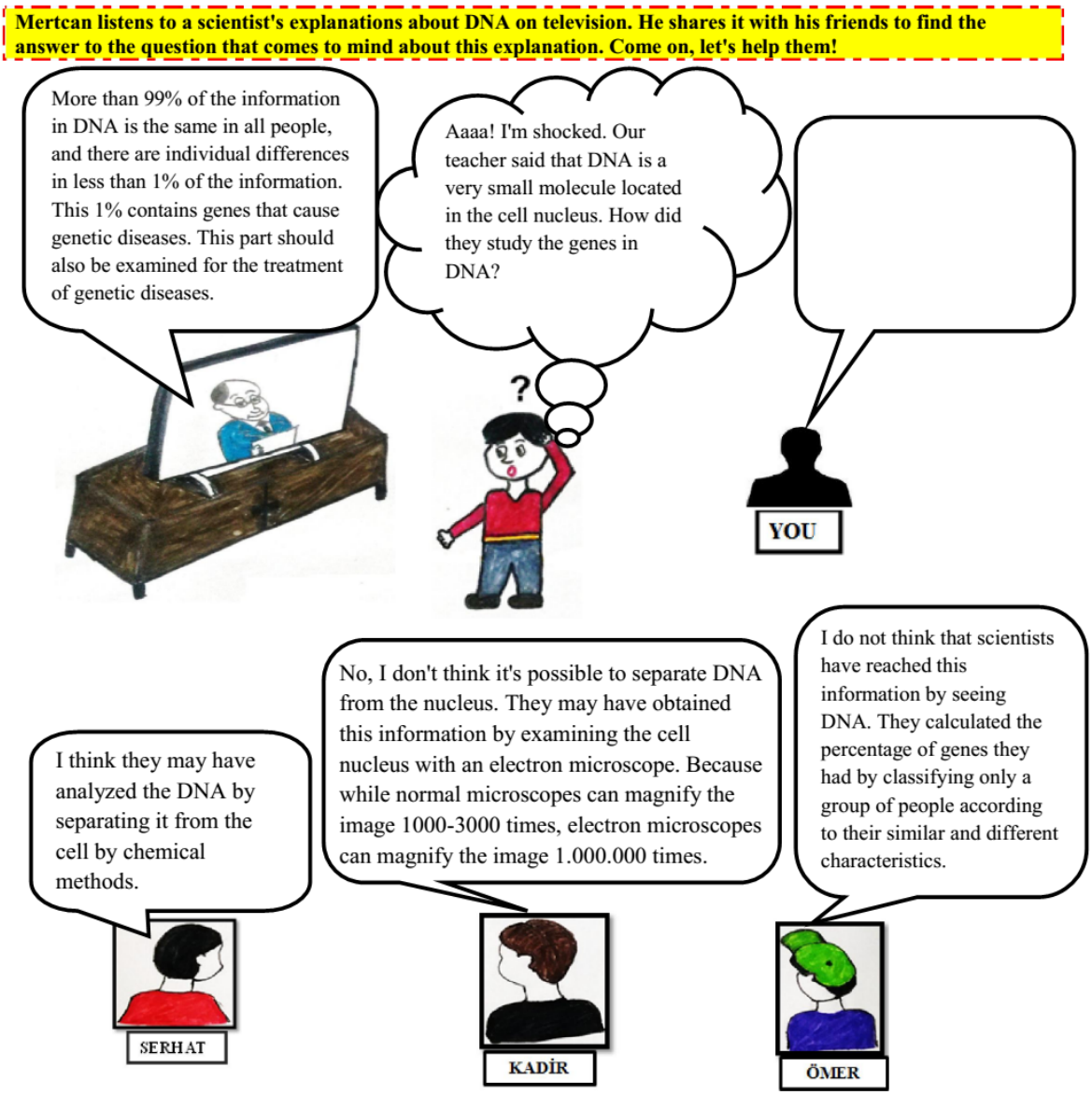


Figure 12. Concept Cartoon at the Stage of Prediction for the Structure of DNA

After answering the question in Figure 11 and the concept cartoon in Figure 12, the volunteer prospective teachers are asked to share their predictions about the open-ended question and the problem situation in the concept cartoon, together with their reasons. While the expression in the speech bubble of the character "Serhat" in the concept cartoons is scientifically correct, the speech bubbles of the characters "Ömer" and "Kadir" contain misconceptions. On the other hand, the "you" character was placed so that if the opinions of the three characters in the concept cartoons were not found correct by the prospective teachers, they could write their thoughts together with their reasons. The purpose of sharing the answers they gave to the concept cartoon together with their reasons in the classroom environment is to ensure that the similar and

different opinions in the reasons are compared and questioned by the prospective teachers. Therefore, the predictions and hypotheses made at this stage form the basis of the next stage.

Observation Stage:

To test the predictions and observations made, the prospective teachers are asked to do the experiment given in Figure 13.

Experiment: Isolation of DNA by Simple Methods

Tools to be used: One onion, grater or knife, a small bowl, one teaspoon of salt, hot water, liquid soap, filter paper, toothpick, alcohol (cologne), glass cup.

Purpose of Experiment: Observing with the naked eye the DNA strands extracted from the onion with simple equipment.

Experimental Procedure:

1. Peel and grate one medium onion into very small pieces.
2. Fill a quarter of a glass with hot water and put a teaspoon of salt in it. Stir until the salt dissolves. Put the grated onions in salt water and mix for 5-10 seconds.
3. In a new glass, add a quarter of a glass of liquid soap, together with a mixture of salt water and onion, and cook for about 5 minutes. Mix slowly, taking care not to foam.
4. Strain the mixture into a clean tea glass with the help of filter paper. (Strain a quarter of a glass is enough.)
5. Add an equal amount of alcohol to the filtered mixture in the glass, very slowly, without allowing the alcohol to mix with the filtered mixture. The alcohol will form a layer on the filtered mixture.
6. After waiting for a while, DNA strands can be observed in the alcohol phase. You can get it with the help of toothpick.

Observations:

Experiment Result:

Figure 13. The Experiment Prepared for the Discovery of the Structure of DNA

While performing the experiment given in Figure 13, prospective teachers should work as a group and divide the work to record the observations on the worksheets. After the experiment, each group is asked to write down their observations and the results of the experiment on their worksheets. Thus, it is ensured that the ideas are shared, compared and the results of the experiment are decided within the group through in-group discussions.

Explanation Stage:

The explanation phase begins by asking the groups questions about the predictions they made and the comparison of the results obtained from the experiment by the researcher conducting the lesson. Thus, by providing an environment for discussion between groups, prospective teachers compare their predictions, the data they obtained from the experiment, and the results with each other. They can also evaluate their learning activity. In this section, some of the

predictions made by the prospective teachers may have been falsified and some may have been confirmed. For example, while many prospective teachers thought that DNA could be observed with an electron microscope since electron microscopes magnified the image 1,000,000 times during the estimation phase, they found that DNA could be made visible by separating it from the cell with simple chemical methods, as a result of the experiment. Then, a worksheet with a summary of the subject and evaluation questions enriched with visuals is distributed to the prospective teachers. The new information about the structure of DNA discovered by the prospective teachers as a result of their experiments and discussions and the role of the processes in the experiment in separating DNA from the cell, respectively, is briefly summarized by the researcher conducting the course. In addition, which character in the concept cartoon is telling the truth is explained and repeated with its reasons. To help the pre-service teachers better understand the explanations and answer the question in the evaluation phase, a summary of the subject explaining the structure of DNA and some images related to the subject were placed on the worksheet. These images and a summary of the subject are given in Figure 14.

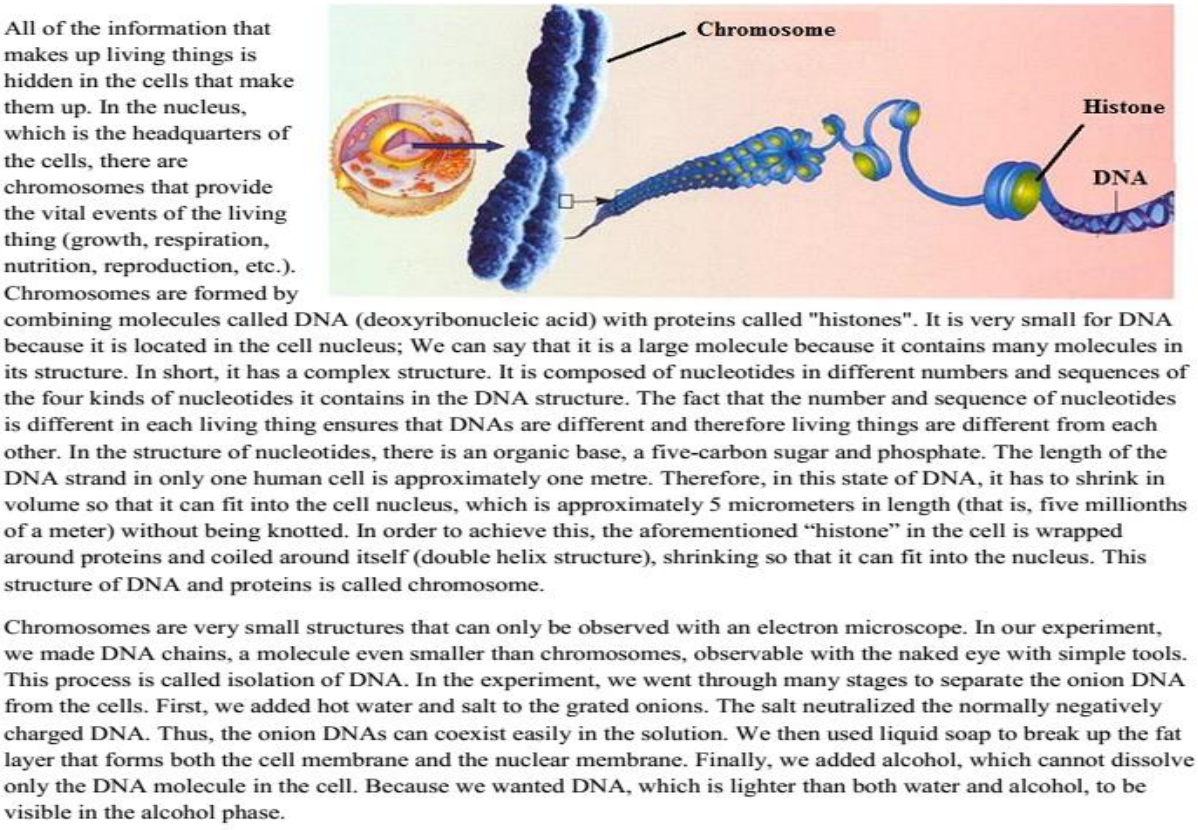


Figure 14. Subject Summary Enriched with Visuals Describing the Structure of DNA (URL-4)

The information in Figure 14 is repeated and the activity is completed after the lesson is summarized.

Part III: Measurement and evaluation

When the target gain of the activity is examined, it is seen that there is a metacognitive gain for understanding the relationship between the units that make up the structure of DNA. This was done in the observation phase of the DNA isolation experiment with simple methods to understand the structure of DNA. Therefore, in the evaluation part, the open-ended question given in Figure 15 was asked to consider and question the importance of the isolation process, which is a fundamental process in understanding the structure of DNA.

1. Explain the importance of DNA isolation in gene technology.

Figure 15.Evaluation Question Prepared for the Structure of DNA

Discussion Conclusion and Suggestions

Within the scope of science teaching laboratory applications-II course, activities based on POE teaching activities for middle school 7th and 8th-grade biology subjects were developed and context-based open-ended questions and concept cartoons were used in the prediction stage. In many studies on POE teaching practices in the related literature, open-ended questions are used in the prediction stage (Akgün et al., 2013; Baladın Duman, 2019; Köse et al., 2003). "Why?", "What?" and "How do we explain this phenomenon?" Since no situation can attract the attention of students in laboratory approaches, which start the lesson with short open-ended questions such as, they may not make an effort to find answers to the questions (Bilen et al., 2011). Therefore, at this stage, students should be asked questions that can stimulate their questioning and prediction skills by giving them problem situations that may attract their attention. As a matter of fact, according to White and Gunstone (1992), during the prediction stage of POE teaching applications, students are asked questions about their prediction skills about a demonstration, experiment or a subject to be presented, and they are asked to explain their reasons. Students' putting forward their predictions with their reasons will positively affect their motivation to learn by making them wonder about the answer to the problem situation and focusing on the lesson. It is stated by Tekin (2008) that in teaching practices in which the POE teaching method is used, students' putting their predictions in writing and comparing them with their observation results and predictions will make them more interested and careful. For this reason, context-based open-ended questions were included in the prediction stage of the

developed activities. Another purpose of the prediction stage is to reveal students' misconceptions in their prior knowledge (Köse et al., 2003). One of the effective techniques in identifying misconceptions is concept cartoons. The results of many studies in the related literature show that concept cartoons are at least as effective as open-ended questions in determining misconceptions (Demir, Uzoğlu, & Büyükkasap, 2012; Uzoğlu, Yıldız, Demir, & Büyükkasap, 2013). Concept cartoons are cartoons that contain the thoughts of at least two characters for the solution of a certain problem situation in daily life. While there is a scientifically correct statement in one of the thought bubbles of the characters in the concept cartoons, there are misconceptions in the related literature in the others. While answering the concept cartoons during the application, the students should explain which character they agree with their reasons. Concept cartoons differ from multiple-choice questions with this feature. As a matter of fact, in the study conducted by Liew and Treagust (1998), it is stated that the use of multiple-choice questions in the prediction stage will limit students' predictions. In addition, sometimes students may not see any of the thoughts of the characters in the concept cartoon as the correct answer. This shows that the student has a different mindset than the misconceptions in the related literature. Therefore, by adding the character "You", which is an empty speech bubble, to the concept cartoons developed within the scope of this study, it is aimed to reveal the misconceptions that are not similar to those in the literature. In POE teaching applications, designing the prediction stage in a way that will enable students to be mentally active helps them to be better motivated to the next stage, the observation stage. For this reason, it can be said that the most important stage in terms of continuity of teaching is the prediction stage.

In this study carried out within the scope of science teaching laboratory-II course, experiments that can be done with simple tools were used in the observation stage of the activities based on POE teaching applications. According to CoHE (2018), one of the aims of the Science Teaching Laboratory Applications -II course is to provide prospective teachers with the ability to design experiments with simple and inexpensive materials for middle school 7th and 8th-grade subjects. Therefore, in the observation stage of the activities developed within the scope of this study, experiments that can be done with simple and inexpensive tools were used to guide the experiments that prospective teachers will use in their future professional lives. Many studies in the related literature show that science experiments with simple tools and equipment have a positive effect on students' cognitive, affective and psychomotor skills (Anılan, Berber, & Suder, 2020; Çeken, 2010; Önen & Çömek, 2011; Uyanık, 2018; Uzal, Erdem, Önen, & Gürdal, 2010; Yüzüak, Yüzüak, & Arslan, 2020). In the study conducted by Önen and Çömek (2011)

by allowing prospective teachers to conduct experiments with simple tools in the Science Teaching Laboratory Applications- II course in the chemistry laboratory; prospective teachers stated that they were considering doing experiments with simple tools in their laboratory classes for various reasons (being simple and understandable, using daily materials, not being time-consuming, etc.). In the study conducted by Uzal et al. (2010), it was determined that 100% of the science teachers and 96% of the classroom teachers, who were given in-service training on science experiments that can be done with simple tools, believed that they could make new experiments by making use of the experiments. From this point of view, it can be said that the use of experiments with simple tools in teaching can be effective in developing a positive attitude towards science lessons. As a matter of fact, in the study conducted by Uyanık (2018), it was seen that experiments with simple tools had a positive effect on students' attitudes towards science courses, academic success, and permanence. Therefore, considering the results of the aforementioned studies, it will be beneficial in many ways to include experiments using simple tools in activity-based studies.

In the explanation stage of POE teaching practices, it is necessary to provide comparisons of students' predictions and observation results within the framework of the constructivist learning approach. The role of the teacher in the explanation stage is to enable students to find information. For this purpose, one of the techniques that teachers can use is the question-answer technique. Teachers should ask questions for students to share their predictions and observations, and to examine the reasons for the differences between their predictions and observations. In particular, one-answer questions that can be answered as "Yes" or "No" should be avoided. The aim here is to enable students to compare different predictions and observations by providing an in-class discussion environment. In the explanation phase of this study, in which activities based on POE teaching practices were developed, some verbally open-ended questions were asked to prospective teachers to compare the predictions in the concept cartoons used at the beginning of the lesson and the observations in the experiments they made. Thus, an in-class discussion environment was created. At the end of the discussions, the prospective teachers agreed on the estimation and observation results in some activities. However, in some activities, it was seen that prospective teachers could not reach a consensus by presenting different predictions and observation results. In this case, some scaffolding questions were asked to the prospective teachers to reach the target acquisition based on the activity. In the related literature, scaffolding questions are mentioned as one of the techniques used in the scaffolding method (Alibali, 2006). The scaffolding method is a process in which the learner

seeks help from any source of information to solve the problem, to bridge the gap between what they know and what they are trying to learn (Perkins, 1991). In this process, the information is not presented to the student, it is provided to discover it with various techniques. One of these techniques is scaffolding questions. Scaffold questions are questions asked to develop, support, and help student skills (Budıa, 2017). The reason why a consensus could not be reached on the results of the experiments may be due to the different data obtained by the groups from the experiment or the different interpretations of the similar data by the groups. For this reason, in this study, each group was asked scaffold questions about what the data they obtained from the experiment were and how they interpreted the data afterward. Thus, by revealing the reasons for the different ideas between the groups, the achievement of the goal of the activity and the formation of a common opinion were ensured. Afterward, worksheets containing a summary of the topic and evaluation questions were distributed to the pre-service teachers. Evaluation questions are open-ended questions that prospective teachers can use their metacognitive skills. The purpose of including a subject summary enriched with various visuals in the worksheet is to create another scaffold that can help pre-service teachers answer the evaluation questions. In the scaffolding method, explanations that can help the student complete the given task, Venn diagrams that outline a topic, flowcharts, etc. are some of the other techniques that can be used with scaffolding questions (Alibali, 2006). In the related literature, many studies are showing the positive effects of using the scaffolding method on teaching (Arı, Peşman, & Baykara, 2017; Karabay, 2020; Mahtari; Wati, Hartini, Misbah, & Dewantara, 2020). In the study conducted by Arı et al. (2017), the effects of teaching methods in reducing misconceptions were compared for prospective teachers with low, medium, and high scientific process skills. Inquiry-based instruction was used in both groups of the study, which was conducted using the quasi-experimental method. However, while the level of guidance was increased by using scaffolding structures in the "reaching conclusion" step of inquiry-based teaching applied in the experimental group, inquiry-based teaching was carried out without using scaffolding structures in the control group. As a result of the study, it was seen that inquiry-based teaching using scaffolding was more effective in reducing the misconceptions of prospective teachers with low scientific process skills about simple electrical circuits. In the single-group, a pretest-posttest quasi-experimental study conducted by Mahtari et al. (2020), PhET simulation and scaffolding questions were included in the teaching of "Ohm's Laws", "Kirchoff's Laws" and "Series and Parallel Circuits" worksheets are used. As a result of the study, it was determined that the worksheets containing PhET simulation and scaffolding questions had a positive effect on the cognitive learning of prospective science teachers. Considering the results of the studies

mentioned above, it is thought that using various scaffolding techniques in teaching practices or activities developed within the framework of the constructivist learning approach will provide convenience for teachers and students.

In the light of the experiences gained from this study carried out within the scope of POE teaching practices, some suggestions for researchers and teachers regarding the development and implementation of their activities are presented below:

- The misconceptions should be determined by scanning the literature on the subject to which the activity will be developed.
- In the prediction stage, concept cartoons containing daily life problem situations related to the subject can be used to improve students' prediction skills and to increase their motivation towards the lesson by feeling the misconceptions they may have.
- Students may have misconceptions different from the misconceptions in the subject and the literature. Empty speech bubbles should be included in the concept cartoons to reveal these misconceptions and for students to write their prediction sentences.
- In the scenario situations in the concept cartoons, the contexts that can attract the attention of the students should be used considering their age and readiness.
- In the observation stage, experiments that can be done with simple tools should be included to be easy, understandable, and not time-consuming.
- To carry out the teaching within the framework of constructivist understanding, scaffolding techniques can be used in the activities to be carried out at the explanation stage.

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