



The Effect of Prediction-Observation-Explanation (POE) Method on Learning of Image Formation by a Plane Mirror and Pre-Service Teachers' Opinions

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Abstract

In this research, we examined the effect of the prediction-observation-explanation (POE) method on learning of image formation by a plane mirror and pre-service teachers' opinions. Twenty pre-service science teachers studying at first grade in the Department of Science Education in Turkey participated in the research. We used a one group pretest–posttest design. In the teaching process, carried out in accordance with the POE method, the pre-service teachers made their own plane mirror by using glass and mirror-effect spray paint, and then analyzed the image of a cube by using these mirrors. We analyzed the data by using the SPSS software and content analysis. As a result of the research, we found that the POE method is effective in the learning of image formation by a plane mirror. Thirteen (65%) pre-service teachers expressed only positive opinions about making a plane mirror by using glass and mirror-effect spray paint; seven (35%) pre-service teachers expressed both positive and negative opinions. The entertaining production process (learning by practicing that mirrors can be made from glass) and gaining experience (like preparing material, learning, and implementing safety rules) were the most common positive opinions, although the irritating smell of the spray paint was the most common negative opinion. Seventeen (85%) pre-service teachers expressed positive opinions and three (15%) pre-service teachers expressed both positive and negative opinions on the organized activity in accordance with the POE method. In consideration of the obtained positive and negative opinions, we found teachers could do such activities to provide a better learning environment.

Keywords: *POE method, image formation by a plane mirror, opinion, pre-service science teacher*

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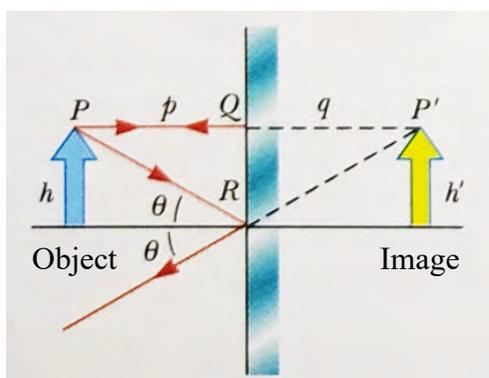
Introduction

Units in the science curriculum include acquisitions that involve science process skills, especially prediction, observation, and explanation (Ministry of National Education [MoNE], 2018). In this context, the curriculum is compatible with the prediction-observation-explanation POE method. So, each stage (prediction-observation-explanation) includes other science process skills in itself. Science process skills include the skills that scientists use during their work, such as observing, measuring, classifying, recording data, making a hypothesis, using data and modeling, changing and controlling variables, and doing an experiment (MoNE, 2018). The first step to be taken, in order to educate students as scientists of the future, is to design activities where science process skills can be gained by doing implementation and to ensure that students actively participate in these activities. One of the activity-based and student-centered teaching strategies is POE (prediction-observation-explanation).

POE is a constructivist teaching method developed by White and Gunstone (Yulianti et al., 2020) where students perform three different tasks: prediction, observation, and explanation (Ojo & Owolabi, 2021; Prabawati et al., 2020). In the prediction stage, students predict the solution of a problem/phenomenon and express the reasons for their prediction. During the observation stage, students experiment to test their predictions. In the explanation stage, students express the differences between their predictions and observations (Alfiyanti et al., 2020; Ojo & Owolabi, 2021). Therefore, POE is a method that offers opportunities for students to actively participate in lessons and practice in terms of critical thinking (Alfiyanti et al., 2020). POE, a teaching method that emphasizes student-centered learning (Tahir et al., 2020), is based on learning by doing, and reveals misconceptions by taking into account students' prior knowledge. Thus, it offers an opportunity for students to evaluate their prior knowledge and structure prior knowledge by comparing it with new information (Ojo & Owolabi, 2021). It also gives an opportunity for students to think about their prior knowledge through newly learned information that can direct students to the adaptation or assimilation process, where they will take the responsibility for their learning (with an inquiry approach) and will follow up by writing their predictions. After the prediction stage, students will experiment and critically reveal their predictions based on the results of the experiment. If there is a difference between the result of the experiment and student prediction, the student will try to rearrange the concept (Tahir et al., 2020).

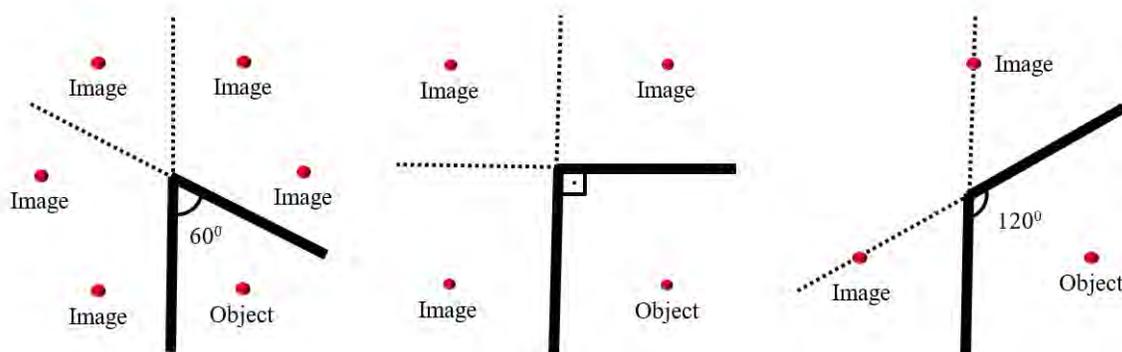
In this research, we examined the effect of the POE method on learning of image formation by a plane mirror and pre-service science teachers' opinions. Whether mirrors that we use for personal purposes or to create multiple images in science centers, plane mirrors (that we frequently use in daily life) are one of the activities that can be used for the POE method.

Figure 1. *Image Formation by a Plane Mirror*



An infinite number of light rays emanate from each point on the object. It is enough to trace only two of an infinite number of light rays to find the place where the image is formed. The first ray starts from point P, follows a horizontal path towards the mirror and reflects on itself. The second ray follows the PR path and is reflected according to the law of reflection as shown in the Figure 1. The observer in front of the mirror thinks that the origin of the two reflected rays comes from the point P' behind the mirror. As a result of the continuation of this process at points other than the P point on the object, the image indicated by the yellow arrow will be formed behind the mirror. Since the triangles PQR and P'QR are similar, the distance between the object and the mirror (p) and the distance between the image and the mirror (q) are equal ($PQ=P'Q$). The size of the object (h) is equal to the size of the image (h'). The image is behind the mirror and is virtual and upright (Serway & Beichner, 2011, pp. 1140–1141).

Figure 2. Number of Images in Mirrors Placed at Different Angles (60° , 90° , 120°)



Literature Review

In the literature, we found various studies that demonstrate the POE method's positive effects. The POE method was effective in developing elementary school fourth-grade students' science process skills (Arslan & Emre, 2020), eighth-grade students' critical thinking skills about pressure (Ulfa et al., 2020), middle school students' critical thinking in learning vibration and wave (Furqani et al., 2018), eighth-grade students' analytical skills in learning physics (Sarah et al., 2021), and 10th-grade students' higher-order thinking skills (Suryamiati et al., 2019). Also, Alfiyanti et al. (2020) reported that the POE method with the Physics Education Technology (PhET) interactive simulations was effective in developing high school students' critical thinking skills.

Additionally, the POE method was effective in academic achievement of elementary school fourth-grade students (Arslan & Emre, 2020); the achievement of high school students in the concepts of work, power, and energy (Nalkiran & Karamustafaoglu, 2020); and the achievement of science students on electric current (Tiftikçi et al., 2017). Also, Yaşar and Baran (2020) revealed that the game-supported POE method was effective in the achievement of high-school 10th-grade students in the pressure and buoyancy unit in a physics lesson. In addition, high-school students stated that this method contributed to their cognitive and affective aspects and that this method should be used in different units of the physics lessons and other lessons.

The POE method was effective in revealing fifth-grade students' thoughts and misconceptions about swimming-sinking (Kıvılcım & Öztuna-Kaplan, 2019), reducing elementary school students' misconceptions about force and motion (Astiti et al., 2020); eliminating the misconceptions of high school 11th-grade

students about heat and temperature (Latifah et al., 2019); misconceptions of high school ninth-grade students about work, power, and energy concepts (Nalkiran & Karamustafaoglu, 2020); and misconceptions of science students about electric current (Tiftikçi et al., 2017). Also, Jubaedah et al. (2019) reported that the PPOEW (predict, plan, observe, explain, write) method was effective in eliminating students' misconceptions about work and energy issues.

The POE method was effective in the fifth-grade students' conceptual change on water density (Yulianti et al., 2020) and the pre-service science teachers' conceptual change about some astronomy concepts (Bozdemir et al., 2017). In addition, the POE method was effective in the teaching of buoyancy (Radovanović & Sliško, 2013), fifth-graders' understanding of air pressure (Fuadi et al., 2020), and middle school students' conceptual mastery in learning vibration and wave (Furqani et al., 2018).

The POE method has positive effects on the achievement and attitudes of seventh-grade students' (Venida & Sigua, 2020) and high school students' performance and attitudes (Ojo & Owolabi, 2021) towards physics. In addition, for the experiment based on the POE method about electricity and magnetism, physics teachers stated that this experiment is important in attracting the attention of students, observing, problem-solving, connecting with life and the subject, and gaining experimental process skills. They expressed that it can be done individually or as a group, and it will improve students' science process skills, psychomotor skills, and attention skills (Tereci et al., 2018).

We summarized the studies on the effectiveness of the POE method and presented this in the Table 1.

Table 1. *The Studies on the Effectiveness of the POE Method*

Author/Authors (Year)	Study Group	The Effectiveness of the POE Method
Sarah et al. (2021)	eighth-grade students	Analytical skills in learning physics
Ojo & Owolabi (2021)	high school students	Performance and attitudes towards physics
Arslan & Emre (2020)	elementary school fourth-grade students	Developing science process skills, academic achievement
Ulfa et al. (2020)	eighth-grade students	Critical thinking skills about pressure
Alfiyanti et al. (2020)	high school students	Developing critical thinking skills (with the Physics Education Technology [PhET] interactive simulations)
Nalkiran & Karamustafaoglu (2020)	high school ninth-grade students	The achievement and misconceptions about work, power, and energy concepts
Yaşar & Baran (2020)	high school 10th-grade students	The achievement in pressure and buoyancy unit in a physics lesson; cognitive and affective aspects (game-supported)
Astiti et al. (2020)	elementary school students	Reducing misconceptions about force and motion
Yulianti et al. (2020)	fifth-grade students	Conceptual change on water density
Fuadi et al. (2020)	fifth-grade students	Understanding of air pressure
Venida & Sigua (2020)	seventh-grade students	The achievement and attitudes towards physics
Suryamiati et al. (2019)	10th-grade students	Higher-order thinking skills

Kıvılcım & Öztuna-Kaplan (2019)	fifth-grade students	Revealing thoughts and misconceptions about swimming–sinking
Latifah et al. (2019)	high school 11th-grade students	Eliminating the misconceptions about heat and temperature
Jubaedah et al. (2019)	students	Eliminating misconceptions about work and energy issues (PPOEW—predict, plan, observe, explain, and write)
Furqani et al. (2018)	middle school students	Conceptual mastery and critical thinking in learning vibration and wave
Tereci et al. (2018)	students	Attracting the attention of students; observing, problem-solving, connecting with life and the subject; gaining experimental process skills; and improving science process skills, psychomotor skills, and attention skills
Tiftikçi et al. (2017)	science students	The achievement and misconceptions about electric current
Bozdemir et al. (2017)	pre-service science teachers	Conceptual change about some astronomy concepts
Radovanović & Sliško (2013)	seventh-grade students	Teaching of buoyancy

Purpose of the Study and Research Questions

This activity is an exercise in teaching pre-service science teachers how to use POE as an instructional technique, making them useful to future students who are learning the method. In this context, we employed the following questions:

1. Does the POE method have an effect on learning of image formation by a plane mirror?
2. How do pre-service science teachers feel about making mirror from glass by using mirror-effect spray paint?
3. How do pre-service science teachers feel about the activity carried out in accordance with the POE method?

Method

Research Model

The design for this study was the one group pretest–posttest design. In this design, we determined the effect of the experimental process as a result of the implementation with a single group. We obtained measurements on the dependent variable of a group by using the same measuring tool as a pretest before the implementation and as a posttest after the implementation. As seen in Table 2, the significance of the difference between the pretest and posttest measurements (O1–O2) of a group (G) is tested in this design (Büyüköztürk et al., 2020, p. 208).

Table 2. *The One Group Pretest-Posttest Design*

Group	Pretest (O ₁)	Implementation Process (X)	Posttest (O ₂)
G	Image formation by a plane-mirror test	Activity form (POE): Examining of the image formation by a plane mirror	Image formation by a plane-mirror test
G			Opinion form

Study Group

The study group included 20 volunteer pre-service science teachers (19 female, one male) studying at first grade in the Department of Science Education in the fall semester of the 2018–2019 academic year in Turkey.

Data Collection Tools

We developed the image formation by a plane-mirror test (pretest and posttest), the activity form, and the opinion form, and used them as data collection tools.

The Image Formation by a Plane-Mirror Test (Pretest and Posttest)

The test consists of five experiments that involve answering the images of a cube for five different experiments with drawing and written explanation.

- The first experiment is supported by drawing the image(s) of a cube placed 5 cm in front of a plane mirror.
- The second experiment is supported by drawing the image(s) of a cube placed between two plane mirrors that are placed opposite each other with their reflective surfaces facing each other, leaving a distance of 10 cm between them.
- The third experiment is supported by drawing the image(s) of a cube placed between two plane mirrors that intersect at an angle of 60° between them.
- The fourth experiment is supported by drawing the image(s) of a cube placed between two plane mirrors that intersect at an angle of 90° between them.
- The fifth experiment is supported by drawing the image(s) of a cube placed between two plane mirrors that intersect at an angle of 120° between them.

We implemented image formation by a plane-mirror test to pre-service teachers as a pretest before the activity and a posttest after the activity.

The Activity Form

The form consists of three stages, named as prediction, observation, and explanation. In the prediction stage, we asked the pre-service teachers to draw images of a cube for five different experiments and support their drawings with written explanations. During the observation stage, we asked them to observe the image of a cube for five different experiments with the mirrors that they designed, and record the results of observation. In the explanation stage, we asked them to compare their predictions with observations and write the similarities and differences between their predictions and observations. In the data collection process, in order to prevent the pre-service teachers from changing their drawings and written explanations in the previous stage, we gave them three separate papers for each stage of the POE, and we collected papers at the end of each stage.

The Opinion Form

The form consists of two open-ended questions. We implemented the opinion form to the pre-service teachers after the activity and gave them 20 minutes to answer the questions. In the first question, we asked the pre-service teachers to write their opinions about making a mirror by using glass and mirror-effect spray paint. In the second question, we asked them to write their opinions about the activity carried out in accordance with the POE method.

Before the activity, we wanted to show them how to make a mirror. They also observed that when they painted the two sides of the mirror, there will be no reflection and no image will be formed. For this reason, we wanted them to use their own prepared plane mirrors instead of giving them ready-made plane mirrors. Therefore, we needed the opinions of pre-service teachers to inform other researchers about the process of making mirror from glass by using mirror-effect spray paint and to remind them about the deficiencies.

Implementation Process

We organized an activity called "Investigation of Image Formation by a Plane Mirror" in accordance with the POE method, and we carried out this activity in the laboratory. Before the activity, we gave information to pre-service teachers about the safety rules they need to pay attention to during the activity, such as wearing masks, protective glasses, a lab coat, and gloves during the preparation of mirrors (by using glass and mirror-effect spray paint). These measures were to prevent the offensive odor of the spray paint and to prevent the dye from contaminating hands and clothing. Pre-service teachers were able to remove their personal protective equipment while determining the number of images.

In the prediction stage, we asked the pre-service teachers to make predictions about the image(s) of a cube placed opposite a plane mirror, between two opposite plane mirrors, and between two intersecting plane mirrors. We then asked them to present their predictions with drawings and written explanations.

During the observation stage, we carried out the activity called "Investigation of Image Formation by a Plane Mirror." The pre-service teachers used two identical pieces of glass, mirror-effect spray paint, a garbage bag, gloves, a lab coat, protective glasses, a mask, colored paper, a protractor, a ruler, and a cube for this activity. The pre-service teachers created their own mirrors using the two identical pieces of glass and mirror-effect spray paint on the garbage bags that they laid on the tables. They used masks, protective glasses, a lab coat, and gloves for protection, and they paid attention to the safety rules during this process. They then observed the images of the cube they placed opposite a plane mirror, between two opposite plane mirrors, and between two plane mirrors intersecting at three different angles (60° , 90° , 120°). During the observation stage, they used plane mirrors they made themselves. They recorded their observations as drawings and written explanations.

In the explanation stage, the pre-service teachers compared their predictions and observations, and then expressed the similarities and differences between their predictions and observations.

Data Analysis

We calculated frequency and percentage values in the analysis of the data obtained from the activity form. We presented examples from the drawings and explanations done by the pre-service teachers.

We examined the given answers to the questions in the image formation by a plane-mirror test as a drawing and an explanation for each question. We gave two points for the correct drawing and two points for the correct explanation; one point for the partially correct drawing and one point for the partially correct explanation; and zero points for the false/blank drawing and zero points for the false/blank explanation to the pre-service teachers' answers. After we scored the questions, we calculated the pretest and posttest scores and

converted them into a 100-point system. The lowest score that can be obtained from the test is zero, the highest score is 100. We saved pretest and posttest scores in an Excel file.

We statistically analyzed the data obtained from the pretest and posttests by using the SPSS software. We used the normality test to determine whether the collected data in pretest and posttest were normally distributed. Since the posttest data were not normal distribution, we used the Wilcoxon Signed Ranks Test for statistical comparison of pretest and posttest results. As two independent researchers, we separately evaluated, scored, and analyzed the data obtained from the pretest and posttest by using the SPSS software and comparing the analysis results. We observed that there was complete harmony between us.

We analyzed the data obtained from the opinion form by using content analysis. We numbered the datasheets (PT1, PT2, ...) for each pre-service teacher and transferred the raw data to the computer. In order to ensure external validity in data analysis, we did a detailed description. As two independent researchers, we separately analyzed the data, and compared and arranged the analysis results. We presented the edited data in the form of categories and codes. We calculated frequency values of categories and codes. In addition, we prepared tables and interpreted them.

In order to make the pre-service teachers' opinions more clear, we presented direct quotations from their answers with the numbers of the pre-service teachers (PT1, PT2, ...). We made a comparison between the two coders to ensure reliability. We computed the coder reliability by using the formula: Agreement = [Number of Agreements / (Number of Disagreements + Number of Agreements) x 100] (Miles & Huberman, 1994). We calculated the reliability between two independent coders as 85.45%.

We collected the data of this research in the fall semester of 2018–2019. Since we used the obtained data before 2020, in the article, it is among the studies that do not require the permission of the ethics committee.

Results

We present the results obtained from the image formation by a plane mirror test, the activity form, and the opinion form under headings.

Results Obtained From the Image Formation by a Plane Mirror Test (Pretest and Posttest)

In order to decide on the type of test to be implemented to the data obtained in the study, we examined whether the data were normally distributed. For a study group consisting of less than 50 persons, we considered the p -value obtained by using the Shapiro-Wilk test. If this value is $p > 0.05$, we accept that the data have normal distribution (Büyüköztürk, 2012, p. 42). For the pretest, $p = 0.204$ ($p > 0.05$) and the pretest data have normal distribution. For the posttest, $p = 0.028$ ($p < 0.05$) and the posttest data are not normal distribution. The skewness coefficient for pretest data is -0,291; the kurtosis coefficient is -0,834; the skewness coefficient for the posttest data is 0.863; we find the kurtosis coefficient as 0.027. Since the skewness and kurtosis values for the pretest and posttest data are within the limits of -1 and +1, we understand that the data have normal distribution. When we examine both the p -value and the skewness coefficient and the kurtosis coefficient together, the pretest data are normal distribution, but the posttest data are not normal distribution. For this reason, we analyzed whether there is a statistically significant difference between pretest and posttest scores by using the Wilcoxon Signed-Ranks Test. We give the test results in Table 3.

Table 3. *Wilcoxon Signed Ranks Test Results for Pretest and Posttest*

Posttest and Pretest	N	Mean Rank	Sum of Ranks	z	p
Negative ranks	0	0.00	0.00	-3.936	0.000*
Positive ranks	20	10.50	210.00		
Ties	0	-	-		

* $p < 0.05$

Table 3 shows that there is a statistically significant difference between the pretest and posttest scores of the pre-service teachers [$z = -3.936$; $p = 0.000$; $p < 0.05$]. Considering the mean rank and the sum of ranks, the difference scores are in favor of the positive ranks. In addition, based on this study, out of 100 score rating in the pretest, the mean of the pre-service teachers' score was 33.25. In the posttest, the mean of their score was 77.50. According to these results, the activity based on the POE method has a significant effect on pre-service teachers' learning of image formation by a plane mirror.

Results Obtained From the Activity Form

We present the data obtained from the activity form under the titles of prediction, observation, and explanation stages.

Prediction Stage

We give the frequency and percentage values of the analysis of the drawings and explanations made by the pre-service teachers during the prediction stage about image formation by a plane mirror in Table 4.

Table 4. *Frequency and Percentage Values of the Analysis of the Drawings and Explanations Made by the Pre-Service Teachers During the Prediction Stage*

Experiments	Prediction															
	Drawing								Explanation							
	Correct		Partially correct		False		No answer		Correct		Partially correct		False		No answer	
	f	%	f	%	f	%	f	%	f	%	f	%	f	%	f	%
First	7	35	13	65	-	-	-	-	11	55	-	-	9	45	-	-
Second	-	-	19	95	-	-	1	5	7	35	2	10	10	50	1	5
Third	-	-	13	65	-	-	7	35	2	10	-	-	10	50	8	40
Fourth	-	-	12	60	-	-	8	40	3	15	-	-	10	50	7	35
Fifth	-	-	10	50	-	-	10	50	2	10	-	-	10	50	8	40

As seen in Table 4, most of the pre-service teachers' drawings were partially correct in the prediction stage, and a small number of pre-service teachers' explanations were correct for the second, third, fourth, and fifth experiments. According to Table 4, the pre-service teachers had difficulty both drawing and explaining. In fact, some pre-service teachers stated that drawing was tiring (PT₂, PT₇, PT₁₅), difficult (PT₄, PT₁₀), boring (PT₇), and challenging (PT₁₂) in their opinions about the POE method.

Observation Stage

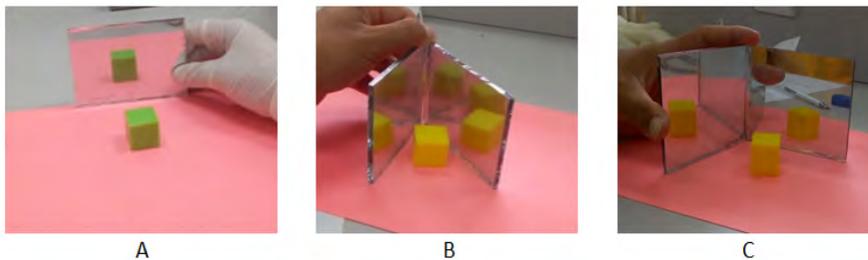
When we examined the data written by the pre-service teachers during the observation process, we understood that there were deficiencies and errors in their predictions. We give some examples from the

visuals of the preparing plane mirrors process in Figure 3. In addition, we give some examples from the visuals of the activity in Figure 4.

Figure 3. *Some Examples from the Visuals of Preparing Plane Mirrors Process*



Figure 4. *Some Examples from the Visuals of the Activity (A: First Experiment, B: Third Experiment, C: Fifth Experiment)*



Explanation Stage

Below are examples, including observations, from the pre-service teachers' compatible and incompatible predictions.

- In fact, at first, I could not predict how we could get the number of images by adjusting mirror and degrees, or how many images would be approximate. I understood it when we experimented. In addition, when two plane mirrors were placed against to each other and a cube was placed at a point between them, I predicted that the image was endless, so it happened. (PT₄)
- The angle in the experiment is 60°: I predicted that two images would be formed. However, I saw six images. The angle in the experiment is 90°: I predicted that three images would be formed. I saw three images. The angle in the experiment is 120°: I predicted that four images would be formed. I saw two images. (PT₁₀)

Results Obtained From the Opinion Form

In Table 5, we analyzed the opinions of the pre-service teachers about making mirrors by using glass and mirror-effect spray paint.

Table 5. *Pre-Service Teachers' Opinions About Making Mirror by Using Glass and Mirror-Effect Spray Paint*

Category	Code	f
Affective effect	Like preparing material	4
	Want to do it again	2
	Looking forward to similar experiments	1
	Want to do research	1
	Feeling happy	1
	Like physics lesson	1
Cognitive effect	Gaining experience	4
	Gaining information	1
	Activating the imagination	1
	Contributing to personal development	1
Learning	Learning by practicing that mirror can be made from glass	5
	Concretizing the subject	2
	Learning by experimenting instead of formulas	1
	Learning by doing and experiencing	1
Production process	Entertaining	9
	Surprising (turning glass into a mirror)	2
	Nice (turning glass into a mirror)	1
	Enjoying (turning glass into a mirror)	1
	Impressive (turning glass into a mirror)	1
	Practical	1
	Simple and easy	1
	Super	1
	Requiring attention	1
Finding the opportunity to prepare your own material	1	
Product	Irritating the smell of the spray paint*	7
	Functional	1
	Beneficial	1
Learning and implementing safety rules	Wonderful	1
	Mask	5
	Glasses	3
	Lab coat	2
	Glove	1
	Learning the rules	2
	Being careful	1

*negative opinion

According to Table 5, the pre-service teachers' opinions are mostly positive. Thirteen (65%) pre-service teachers' opinions are positive, and seven (35%) pre-service teachers' opinions included both positive and negative expressions. The entertaining production process, learning by practicing (that a mirror can be made

from glass), gaining experience, like preparing material, learning, and implementing safety rules were the most common positive opinions. Finding the smell of the spray paint irritating was the most common negative opinion of some pre-service teachers (PT₁, PT₃, PT₄, PT₅, PT₆, PT₈, PT₁₅). We give some examples from the positive and negative opinions of pre-service teachers below as direct quotations.

Positive Opinions

- I liked the experiment very much. I have never done a mirror before. Formally, I [was] enlightened. I liked the spraying study very much, I always wanted to do it.... I got an idea about the plane mirror. When I go home, I will do detailed research. (PT₁)
- It was very entertaining but requiring attention production. It was very nice to transform the materials into each other that we use every moment of our lives. Of course, we should wear a lab coat, glasses, and mask, that is, first, we start by providing safety. (PT₅)

Negative Opinions

- The smell of the spray paint was irritating, but thanks to the mask and glasses, there was no problem. (PT₆)
- The spray paint smelled very heavy. (PT₁₅)

Some pre-service teachers stated that the process contributed to the use of protractors. The expressions of the pre-service teachers are as follows:

- I remembered finding an angle.... (PT₂)
- I learned to use a protractor with angles.... (PT₁₁)
- I remembered by using a protractor and finding an angle again. (PT₂₀)

We analyzed the pre-service teachers' opinions about the activity carried out in accordance with the POE method and give them in Table 6.

Table 6. Pre-Service Teachers' Opinions About the Activity Carried Out in Accordance With the POE Method

Category	Code	f
Learning	Permanent	5
	Visually	1
	Intellectually	1
	By doing and experiencing	1
	By proceeding step by step	1
Process	Nice	8
	Entertaining	4
	Functional	2
	Being good of the gradual progress	2
	Beneficial	1
	Logical	1
	Interesting	1
	Magnificent	1
	Taking a long time*	2
Being boring of answering similar questions*	1	
Result	Seeing the difference between prediction and observation	8
	Amazing	2

Becoming aware of the wrongs	2
Becoming aware of the wrongs and correcting them	2
Becoming aware of the missing	1
Learning new information and improvement	1
Improvement by commenting	1

*negative opinion

In Table 6, we see that the pre-service teachers' opinions are mostly positive. Seventeen (85%) pre-service teachers' opinions were positive, but three (15%) pre-service teachers' opinions were both positive and negative. Permanent learning, nice process, and seeing the difference between prediction and observation were the most common positive opinions. Three pre-service teachers stated that it took a long time (PT₁₀, PT₁₆) and answering similar questions was boring (PT₁) as negative opinions. We give some examples from the positive and negative opinions of pre-service science teachers below as direct quotations.

Positive Opinions

- I have seen that the number of images changes according to the angles. I learned many things by seeing. Previously, I could not understand from the books that the images were formed according to the angles in the mirror. Here, I could easily understand with our observations.... (PT₃)
- It is a very positive implementation because in this way we can compare our opinions before and after the experiment. We saw where we did wrong as a result of our own efforts and this way, it remained in our minds very much. (PT₁₃)
- After experimenting, I encountered a few unexpected results. I've never heard of this method before. But it is a very good study in terms of attracting attention. It's a good study to learn the differences between prediction and results of an experiment. (PT₁₅)
- In the prediction, we already mentioned the things that we knew wrong. But when it came to the observation stage, I saw what was right and what was wrong. While I logically thought of very different numbers in the prediction, I was very surprised when we experimented. It was a good study. (PT₁₇)

Negative Opinions

- I'm just a little bored to answer the similar questions.... (PT₁)
- It takes too long. Example: The work of filling the paper one by one.... (PT₁₆)

Six pre-service teachers (PT₂, PT₄, PT₇, PT₁₀, PT₁₂, PT₁₅) stated that drawing was difficult, tiring, challenging, or boring, while they filled out paper given to them at different stages of the activity process based on the POE method. Besides, two pre-service teachers (PT₆, PT₈) expressed that they did a lot of drawing.

Conclusion, Discussion, and Suggestions

In this research, we examined the effect of the POE method on the learning of image formation by a plane mirror and the opinions of pre-service teachers. As a result of the research, we determined that the POE method was effective in the learning of image formation by a plane mirror. This result of the study was consistent with the literature. According to the literature, the POE method is effective in concept development and change (Bozdemir et al., 2017; Yulianti et al., 2020), understanding (Fuadi et al., 2020), learning (Furqani et al., 2018), and teaching (Radovanović & Sliško, 2013).

All the pre-service teachers' opinions about making mirrors from glass by using a mirror-effect spray paint are positive. Some pre-service teachers frequently expressed positive opinions as entertaining production process; learning by practicing that mirrors can be made from glass; gaining experience, like preparing material,

learning, and implementing safety rules. Seven (35%) pre-service teachers stated that the smell of the spray paint was irritating as a negative opinion.

All pre-service teachers' opinions about the activity carried out in accordance with the POE method are positive. The positive opinions are frequently stated as permanent learning, a nice process, seeing the difference between prediction and observation. According to the literature that supports this result, the implementations carried out with the POE method are effective in permanent learning (Bilen & Köse, 2012; Güngör & Özkan, 2017a, 2017b; Tokur, 2011).

In the study, three (15%) pre-service teachers expressed negative opinions that the process took a long time, and answering similar questions was boring. Similarly, science teachers stated that lessons that are not carefully planned in the POE strategy could become a waste of time, and the strategy is time consuming (Venida & Sigua, 2020). Pre-service classroom teachers also expressed that the POE method is time consuming (Bilen et al., 2016). Palmer (1995) revealed that pre-service teachers did practices with primary school students based on the POE method within the scope of physics, and they perceive the time-consuming nature of the process as a problem.

In the study, some pre-service science teachers stated that the activity process was nice, entertaining, and interesting. This result of the study was consistent with the literature. In the literature, physics teachers expressed that an experimental activity based on the POE method was important in attracting the attention of students (Tereci et al., 2018). High school students, on the other hand, reported that they were satisfied with the POE method, and physics lessons were no longer boring (Yaşar & Baran, 2020).

In consideration of the obtained positive and negative opinions, teachers could do such activities to provide a better learning environment. Teachers could examine characteristics of the image formation using curved mirrors (by making mirrors from convex and concave glasses using spray paint). Teachers and researchers could adapt a similar activity for image formation by using a convex mirror and a concave mirror.

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