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EFFECTS OF POE ON PRE-SCHOOL STUDENTS' CRITICAL THINKING AND POE SKILLS

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Abstract

Apart from basic skills such as self-care and speaking, higher-order cognitive skills including inquiry, critical thinking, and scientific thinking can develop during early childhood. Thus, it is crucial to employ teaching methods that support the development of higher-order cognitive skills in these age groups and ensure that these children systematically use such skills. This study aimed to investigate the effects of the POE (Predict-Observe-Explain) method on the POE and critical thinking skills during early childhood. In this context, 27 pre-school students participated in the study, which involved an experimental design and was carried out for six weeks. In the study, the data collected by using quantitative and qualitative data collection tools were analyzed using appropriate analysis methods. The researchers compared the effects of scientific experiments prepared in line with the POE and gamification on students' critical thinking skills through philosophical inquiry (CTSPI) and POE skills, and skills that constitute the sub-dimensions of these skills. The findings revealed that in early childhood education the POE was more effective than gamification in developing students' critical thinking and POE skills. Similarly, teachers participating in the research process thought that the POE was more effective than gamification in motivating students and turning their attention to teaching processes. Considering the results, the POE is recommended to be used in early childhood education, especially in transferring scientific content in the fields of science.

Keywords: Predict observe explain, critical thinking, early childhood education.

INTRODUCTION

The skills used in science are among the basic competencies that individuals use to produce solutions to the problems encountered in daily life. These skills begin to develop during early childhood and that are far beyond the special abilities that researchers use in conducting scientific studies (Jacobson & Bergman, 1980). The child, driven by the natural sense of curiosity, uses these skills while inquiring and making sense of anything unknown to him/her. Besides ensuring the construction of scientific content, what is aimed at teaching environments is to enable individuals to realize, develop, and use these skills systematically and effectively (Padilla, 1990). In this context, teaching methods and techniques used in teaching processes (especially in science teaching) are expected to enable students not only to construct scientific content more easily but also to develop these skills, such as 21st-century skills, scientific process skills, etc. (Anderson, 2002). On the other hand, some of the methods and techniques used in teaching processes are more effective in constructing the scientific content while others foster different skills of the students. In this case, considering the development levels of the students and the characteristics of their education levels (such as pre-school, primary school, and high school), the question is: Should we use the one which is effective in constructing the contents or the one which is effective in developing skills? The answer to this question requires the use of the method appropriate to the developmental level of the students and the basic objectives of the teaching level. Thus, in pre-school education during which children gain basic competencies and skills, methods ensuring the development of basic and advanced skills in children should be at the top of the list, and as the level goes up, methods ensuring the construction of scientific content and the development of skills should be employed more (Harms & Yager, 1980). Considering pre-school education processes and the characteristics of the students in this process, it is understood that these students develop basic skills (eating, drinking, speaking, simple writing, drawing, and socialization skills) as well as basic scientific skills (such as prediction and observation) (Jacobson & Bergman, 1980). Therefore, the teaching methods and techniques used at the pre-school level should be accommodated in a manner to allow students to foster basic life, inquiry, and scientific thinking skills and to use these skills systematically and efficiently (Harms & Yager, 1980).

The POE covers the most basic stages of argumentation. It involves asking students to make predictions about the presented problem situation, observe the applications, and make explanations on observations through the construction of content by grasping the accuracy/wrongness of their predictions. In this way, apart from constructing the scientific content, students develop skills in predicting, observing, and explaining as well as inquiring (Alexander, Haysom, & Bowen, 2010; White, & Gunstone, 1992).

The POE helps students develop basic scientific skills (prediction, observation, and explanation) and inquiry skills and structure the scientific content with active participation (Champagne, Klopfer, & Anderson, 1980; Gunstone, 1990). Since this approach was introduced to the literature many years ago and is accepted as an effective method, it has been studied in a great amount. When the studies in question are classified according to sample/study groups to have a good grasp of the studies and the results more easily, the POE is observed to be studied on preservice teachers more frequently as it is a teaching method. It has been emphasized in basic laboratory implementations on preservice teachers with various dimensions that the POE proves to be instrumental in the development of academic achievement, permanence, conceptual understanding, scientific process skills, attitudes, and helps identify and eliminate the misconceptions that preservice teachers have towards the selected scientific content (Ayvacı, 2013; Banawi, Sopandi, Kadarohman, & Solehuddin, 2019; Baltacı & Yıldız, 2018; Bilen & Aydogdu, 2010; Güleşir, Aydemir, Sergüzel, Uzel, & Gül. 2020; Harman, 2014; Hilario, 2015; Köklükaya & Yıldırım, 2018; Özdemir, 2011; Tiftikçi, Yüksel, Koç, & Çıbık, 2017; Yavuz & Çelik, 2013). It is reported that preservice teachers perceive the POE as an effective, but time-consuming method that is difficult to apply (Güngör & Özkan, 2017). Studies focusing on the effects of the POE on high school students reveal that it fosters the understanding of scientific content offered to students while increasing academic success, interest in physics, improving metacognitive skills and attitudes (Karadeniz, 2019; Rusçuklu & Özdilek, 2019; Treagust, Mthembu, & Chandrasegaran, 2014; Yaşar & Baran, 2020).

Similarly, studies conducted at different levels and courses at the primary education level revealed its effectiveness in the development of the students' scientific process skills, concept learning, academic achievement, conceptual meanings, critical thinking skills, mental models, and attitudes (Akarsu, 2018; Arsy, Prasetyo, & Subali, 2019; Jasdilla, Fitria, & Sopandi, 2019; Kara, 2017; Nana, Akhyar, & Rochsantiningsih, 2014; Özçelik, 2019; Palmer, 1995; Rini, Suryani, & Fadhilah, 2018; Rosdianto & Murdani, 2017; Sünkür, 2013). In a study conducted at the primary education level, it was found that the POE was effective in terms of predictions and explanations (Schönborn, Haglund, & Xie, 2014).

Studies on pre-school groups, the target groups in this study, mainly deal with the subject based on argumentation and its effects. It is thought that this is due to the detection that not only the predictive and observational skills of the children but also their argument-formation skills have improved (Dunn, Bretherton, & Munn, 1987).

It is understood that in this age group, topics such as argumentation, selection of strong arguments, argumentation-language development, and culture-argumentation have been investigated. In an experimental study conducted with the participation of 84 children aged 3-5; Mercier, Bernard, and Clément (2014) stated that among the argument examples presented, children chose the stronger one.

In addition, it is stated that children were affected by the circular argument and the competence of the individual who defends the argument. In another study conducted in this context, Zadunaisky & Blum-Kulka (2010) stated that peer discussions were effective on children's cultural and social development and set a strategy to determine the effects of argumentation on children's discursive and developmental level. In another study, Zadunaisky (2011) conducted focus group interviews with 15 pre-school students, reporting that children not only elaborated on them but also built arguments.

One of the few studies that tested the effects of the POE in this age group was carried out by Hsu & et al. in 2011 with 50 pre-school students. In the experimentally designed study, computer-assisted games developed for the concept of shadow were presented to one group with the POE and as game-based to the other group. According to the findings obtained through interviews in the study, the researchers found that POE-supported applications were much more effective in the development of the concept of shadow in children. 15 public school and 15 private school students participated in another experimental study aimed at revealing the effects of the philosophy curriculum with children on critical thinking skills in pre-school groups (Karadağ & Demirtaş, 2018). The researchers concluded that the philosophy curriculum with children increased students' critical thinking skills in both groups (Karadağ & Demirtaş, 2018).

It has been observed that studies have been conducted on the effects of the argumentation approach on the development of basic skills in these age groups (discussing, building arguments, and choosing the strong one, language, and social development) and the confirmation of the presence of argumentation skills. Considering science education, it is emphasized in the literature that science teaching should start at an early age, and the acquisition of basic scientific and inquiry skills in early childhood is essential in terms of preparation for subsequent education levels (Gullo, 2006; Marek, & Cavallo, 1997; Ravanis & Bagakis, 1998). In this context, the studies conducted in this field are considered insufficient to explain the effects of argumentation and related methods (such as the POE). Argumentation and related methods both foster socio-cultural skills and basic scientific skills for the nature of science and science fields (Erduran & Jiménez-Aleixandre, 2008; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). However, there is a lack of research on pre-school groups.

It seems to be necessary to investigate the effects of the POE, which has proven its effectiveness in the development of scientific thinking and process skills in other age groups, in early childhood, and to conduct studies on how to use it more effectively. Similarly, it was emphasized that skills of prediction, observation, and explanation were improved in these age groups. However, to what extent these children can use these skills in basic science fields (such as physics, chemistry, biology), in which fields of science they can better inquire about, and the underlying reasons are among the issues that need to be researched.

This study has been designed to investigate the effect of the argumentation approach-based POE on the development of critical thinking skills through basic scientific process and inquiry in pre-school groups and to investigate to what extent these age groups can use basic scientific skills in basic science fields such as physics, chemistry, and biology. The research questions focused on the study are:

To what extent do scientific experiments, prepared according to the POE and gamification, effect the development of children's basic scientific process skills (POE)?

To what extent do scientific experiments, prepared according to the POE and gamification, effect the development of the students' critical thinking skills through inquiry?

How do pre-school teachers and science education experts evaluate the value of using the POE in early childhood?

METHOD

In this study, the effects of the POE on pre-school students' critical thinking and POE skills through philosophical inquiry were investigated. The study employed pre-test and post-test control group quasi-experimental design (Campbell & Stanley, 2015). The research process and steps are explained in detail below.

Research Design

In this quasi-experimental designed study, students were divided into two groups as experimental and control via random assignment. Before the implementation, the measurement tools determined in both groups were applied as a pre-test. While the activities developed by the researcher in the control group were implemented in company with the methods used in the school curriculum, they were implemented using the POE in the experimental group. During the 6-week implementation period, the implementations were recorded on video. At the end of the implementation, measurement tools (The critical thinking skills through philosophical inquiry scale (CTSPI) and The POE Observation Form) were applied to the groups as a post-test and the implementation was terminated after taking the opinions of the teachers and observers (science experts) who participated in the implementation. The research design is presented in Table 1.

Table1. Research design

Group	Preparation Process	Pretest	Implementation	Posttest
Experimental Group	Planning Activities and Pilot Scheme	**$Ö_1$-F_1**	POE Activities	**$Ö_1$-F_1-F_2-F_3**
Control Group		**$Ö_1$-F_1**	Activities	**$Ö_1$-F_1-F_2-F_3**

$Ö_1$: The critical thinking skills through philosophical inquiry scale (CTSPI), **F_1:** The POE Observation Form, **F_2:** The Teacher Observation Form, **F_3:** The Science Expert Observation Form

Study Group

Four pre-school teachers, 27 students (aged 5-6) attending 2 different classes of a private pre-school, and 2 teachers, who were in charge of each class, participated in the study. Students in this school receive education for 2 years and the teachers work as class teachers during this period. Necessary permissions were obtained from the institution for the implementation. Furthermore, families were informed and their permission was obtained to video record the process. Identities of students were kept strictly confidential. Twelve of the students in the study group were female and 15 of them were male. In the study, the classes were selected randomly and one of them was the experimental group while the other was the control group. The teachers were in the same group with the students they were responsible for, and thus 2 of them were in the experimental group, and the other 2 in the control group, as observers. Two science experts (1 in the control group, 1 in the experimental group) participated in the implementations in the experimental and control groups as observers. One of the researchers conducting an activity with students presented in Image 1.

Research Process and Implementations

In the preparation stage, 6 acquisitions which are among the acquisitions in the school curriculum, and related to the fields of physics, chemistry, and biology were determined.

Then, 6 activities were prepared in accordance with the acquisitions and the development characteristics of the students related to the specified fields of science. Two of these activities were biology-related (Which one is my house, don't eat it, eat me! (An expression of cuteness)), 2 of them were physics-related (Who is slow, who will jump first), and 2 of them were chemistry-related (Whose scent is ahead, why my colour has changed). The activities were presented to science experts and pre-school teachers to ask for an evaluation of the suitability for the levels of the students and science fields. A pilot scheme was conducted with the participation of 6 students from the same school who did not participate in the experimental study. At the end of the process,

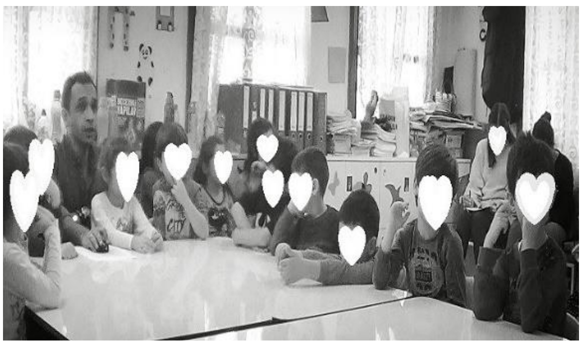

Image 1. An image of the implementation process

it was decided that the activities were suitable for the main implementation. Before the implementation started, the teachers were asked to fill the Critical Thinking Skills through Philosophical Inquiry Scale (CTSPI) for the students they were previously responsible for, and the POE observation form developed by the researcher. Brief information was given to the teachers about how to use both measurement tools. Following the pre-tests, the same activities were applied to both groups for 2 hours a week. The activities were applied in the experimental group through the POE and as game activity in the control group for a total of 12 hours. First, 1 biology, 1 chemistry, and 1 physics activity were conducted, and then 1 biology, 1 chemistry, and 1 physics activity were conducted, respectively, with an attempt to prevent the effect of scientific fields on the results of the study. In the implementation of the activities, short videos were shown to the students in the experimental group to make them realize the problem situation and then they were asked to predict the reason for the event. Then, the activities were conducted to allow them to make observations. Each student was given time to explain whether their predictions were correct or not, based on their observations. In addition, the students were allowed to have scientific discussions by asking questions that would create a discussion environment among them. At the end of the process, small rewards were given to the students who made correct predictions and explanations. In the control group, the applications were carried out with the traditional gamification frequently used by teachers. Activities were introduced to the students as a game and applied in this way. The implementation process in both groups was videotaped. Teachers and science experts joined the implementation as external observers and evaluated the students at the end of each experiment using the POE observation form. Thus, data on the development of the students throughout the process was obtained. After the implementation, the teachers filled in the CTSPI again for the students in the group they joined. Finally, video recordings were distributed to the teachers and science experts to fill in the POE observation forms again. At the end of the process, the teachers and experts who joined the experimental group were interviewed for 1 hour with semi-structured interview questions, and their opinions about the implementation process were asked and finally the process was terminated.

Data Collection Tools

The Critical Thinking Skills through Philosophical Inquiry Scale (CTSPI)

The measurement tool, developed by Karadağ, Demirtaş, & Yıldız (2017) to determine the critical thinking skills of the students aged 5-6, consists of 3 sub-dimensions as "Philosophical Inquiry", "Language and Cognitive Skills", and "Question Formation" and a total of 38 items. It is a 5-point Likert-type scale.

The Critical Thinking Skills through Philosophical Inquiry Scale (CTSPI) for students aged 5-6					
Acquisition/Indicator	1	2	3	4	5
S/he focuses on the stimulus (story, picture, etc.) presented for a philosophical discussion.					
1. S/he reflects on the stimulus (story, picture, etc.) presented for a philosophical discussion.					
2. S/he shares thoughts on the stimulus (story, picture, etc.) presented for a philosophical discussion with the group.					
S/he forms questions related to a philosophical topic of discussion.					
1. S/he forms questions of “What” related to a philosophical topic of discussion.					
2. S/he forms questions of “How” related to a philosophical topic of discussion.					
S/he expresses herself/himself creatively.					
1. S/he expresses feelings genuinely.					
2. S/he expresses thoughts genuinely.					

Figure 1. Sample items of the critical thinking skills through philosophical inquiry scale (CTSPI).

The researchers calculated the internal consistency coefficients of the measurement tool (Philosophical Inquiry, Language and Cognitive Skills, Question formation, and General Total) as .974, .955, .983, and .986 respectively. The measurement tool is filled in by the teacher on behalf of the student. The general structure of the measurement tool is presented in Figure 1.

The POE Form

The form developed by the researcher was used for teachers and experts participating in the study to observe during the implementation process. The characteristics of prediction, observation, and explanation skills included in the POE and Scientific Process Skills (SPS) while developing the forms were researched and their general characteristics were determined (Padilla, 1990). The form created in line with the research was presented to experts in the field of measurement to obtain their opinions its validity. Experts stated that the form is applicable. The general structure of the POE evaluation form is presented in Figure 2.

The POE Form

This form has been prepared to evaluate your students' ability to predict (formulation of hypothesis), observe, and explain in the implementation process of the activities. During the evaluation process, each student will be evaluated separately for each experiment. During the evaluation, you are asked to score from 1 to 10 for the three specified skills of the students.

While scoring, you are expected to set criteria based on the characteristics of the skills, whether students use clear and scientific expressions to demonstrate the relevant skills, and how such expressions are consistent with the process. Below are some questions taken as a basis for scoring by the observers:

Prediction; Could the students clearly state the reason for the problem situation you presented to them and the suggestion that could be a solution to this problem situation? Do the students use scientific expressions while expressing the prediction and solution offer? Are their predictions consistent with the activity?

Observation; Could the students catch the points that would determine the problem situation while watching the experimental process? Could the students give consistent answers to your guiding questions in the process? To what extent did they catch the important points of the experiment?

Explanation; To what extent did the students explain their predictions scientifically using their observations and reasoning at the end of the experiment?

Group	Identity	Prediction	Observation	Explanation	Total
E	Student A	3	3	1	7
C	Student B	4	3	2	9

Figure 2. The sample POE form and sample scoring

Figure 2 demonstrates that there were 4 different scores for each student in the POE form containing prediction, observation, explanation, and total. Observers can score between 1 and 10 for each field (prediction, observation, and explanation) for each student. The sum of the scores given in 3 fields provides the POE total score. The POE scores were grouped about the general grouping method in educational processes. Any skill or achievement score out of 100 in educational processes is considered low between 0-20, acceptable between 20-40, moderate between 40-60, good between 60-80, and very good between 80-100. Accordingly, the scores obtained from the POE observation form are grouped into 5 categories as (a) low level ($a \leq 2$), acceptable level ($2 < a \leq 4$), moderate level ($4 < a \leq 6$), good level ($6 < a \leq 8$), and very good level ($8 < a \leq 10$). There were also guidelines prepared by using Harlen (1999) and Padilla (1990) regarding the observers' correct evaluation of prediction, observation, and explanation skills. Guidelines contain explanatory information about the definition of prediction, observation, and explanation skills, which are the steps of the POE and included in SPS, their characteristics, and the characteristics that the observer should take into account.

Science Expert and the Teacher Interview Form

A semi-structured interview was held with the teachers and science experts in the experimental group to get their opinions about the POE and implementation process. The form containing the interview questions was developed by the researchers, included 2 questions about the characteristics of the POE and the activities as well as the effects of the implementation. Questions included in the teacher interview form were as follows: "Did you find the method effective? Why?" and "Would you like to use this method in your lessons later? Why?" Questions included in the science expert interview form were as follows: “Did you find the method suitable for the level of the students? Why?” and “Did you find the selected experiments in the fields of science suitable to the level of the students? Why?” Interview forms were used to get the opinions of 2 teachers and 1 science expert as observers in the experimental group.

Data Collection and Analyses

The data on the CTSPI was obtained through the implementation of the scale. Four teachers (2 in the experimental group, 2 in the control group) in charge of the study groups filled out the measurement tool separately for each student in their group before the first implementation and at the end of the sixth implementation. The post-test scores of the students were obtained by taking the arithmetic mean of the pre-test scores given by 2 teachers in each group for the same student and of the scores given by the teachers for the post-test. The data obtained from the measurement tool were analysed after being transferred to the SPSS. At the end of the implementation, the pre-test and post-test scores of the students were compared to determine the change in the CTSPI while descriptive statistics, parametric, and non-parametric analyses were conducted on these scores. The data on the POE skills of the students were obtained from the POE form. After each implementation, 2 teachers and 1 expert in each group filled out the POE form separately for the students they were responsible for. The arithmetic mean of the POE score of the student given by 2 teachers and 1 expert refers to the student's POE 1 score for that experiment. To increase the reliability of the data obtained from the POE form, video recordings were given to the experts and teachers 15 days after the implementation to ask for a re-evaluation of the study groups they were responsible for through the POE form as specified in the implementation process. Thus, the student's POE 2 score was obtained for that experiment by taking the arithmetic mean of the scores given by 2 teachers and 1 expert for the same student. The Kappa analysis value on the POE 1 scores obtained from the evaluations of teachers and experts in the process for the same student and the POE 2 scores obtained from the evaluations in the video recording was calculated as .90. This means that the POE 1 and POE 2 scores of the experts and teachers were highly compatible, which shows that the data were reliable. The student's POE scores were obtained for each experiment by taking the arithmetic mean of the students' POE 1 and POE 2 scores. The POE score obtained by the students at the end of the first experiment was accepted as the pre-test while the POE score obtained at the end of the sixth experiment was accepted as the post-test score. At the end of the implementation process, the POE pre-test and post-test scores were compared statistically and descriptive statistics, parametric and non-parametric analyses were conducted on the data to determine the changes in their POE skills. The researcher determined how the POE skills of the students changed in the process through a graphical representation of the POE scores of the students from each experiment.

The opinions of the teachers and experts about the process and the POE method were determined by semi-structured interview forms. Content analysis was made on the data from the interview form. The themes obtained from the responses given by the experts and teachers are presented in the findings.

RESULTS

Normality tests related to the data obtained from the quantitative measurement tools (the POE observation form and the CTSPI) used in the study are presented in Table 2.

Table 2. Normality tests related to the students’ scores of the POE and the CTSPI

Measurement Tools		Shapiro-Wilk	
	Mean	Std.Dev.	p
The CTSPI pre-test	136.81	.754	.000
The CTSPI post-test	154.81	.716	.000
The POE pre-test	13.93	.946	.175
The POE post-test	18.00	.917	.053

Table 2 reveals that the pre-test and post-test scores taken by the students from the CTSPI scale and its sub-dimensions do not comply with the normal distribution, and the POE pre-test and post-test scores show a normal distribution (Dallal & İlkinsen, 1986). Accordingly, non-parametric tests were applied on the CTSPI scores of the students and parametric tests on the POE scores.

Table 3. The Wilcoxon signed rank test findings related to the pre-test and post-test scores of the experimental group students from the CTSPI and its sub-dimensions

Measurement Tools	Groups	N	Mean	Sum of Ranks	Mean Rank	z	p
The Philosophical Inquiry Sub-Dimension Pre-test and Post-test	Negative rank Positive rank Equal	12 1 1	1 7.5	90 1.00	7.50 1.00	-3.112	.002*
Cognitive Skills Sub-dimension Pre-test and Post-test	Negative rank Positive rank Equal	13 0 1	.00 7	91 0	7.00 0	-3.182	.001*
Inquiry, Question Formation Skills Sub-dimensions Pre-test and Post-test	Negative rank Positive rank Equal	10 3 1	5.67 7.40	74,0 17.0	7.40 5.67	-2.014	.044*
The CTSPI Pre-test and Post-test	Negative rank Positive rank Equal	14 0 0	.00 7.50	105 0	7.5 0	-3.297	.001*

*p<.05

Table 3 reveals that there is a significant difference (p <.05) between the pre-test and post-test scores of the students in the experimental group from the CTSPI and its sub-dimensions (p<.05), which is positive in favor of the post-tests. Accordingly, the experimental group students' skills in the CTSPI and its sub-dimensions improved significantly after the implementation.

Table 4. The Wilcoxon signed rank test findings related to the pre-test and post-test scores of the control group students from the CTSPI and its sub-dimensions

Measurement tools	Groups	N	Mean	Sum of Ranks	Mean Rank	z	p
The Philosophical Inquiry Sub-Dimension Pre-test and Post-test	Negative rank Positive rank Equal	11 1 1	1.50 6.95	76.50 1.50	6.95 1.50	-2.950	.003*
Cognitive Skills Sub-dimension Pre-test and Post-test	Negative rank Positive rank Equal	8 3 2	4.00 6.75	54.00 12.00	6.75 4.00	-1.891	.059*
Inquiry, Question Formation Skills Sub-dimensions Pre-test and Post-test	Negative rank Positive rank Equal	7 2 4	1.75 5.93	41.50 3.50	5.93 1.75	-2.263	.024*
The CTSPI Pre-test and Post-test	Negative rank Positive rank Equal	12 0 1	12.00 6.00	78,00 0,00	6.50 0.00	-3.062	.002*

*p<.05

Table 4 reveals that there is a significant difference (p<.05) between the pre-test and post-test scores of the students in the control group from the CTSPI and the philosophical inquiry and question formation sub-dimensions (p<.05), which is positive in favor of the post-tests. Accordingly, the control group students' skills in the CTSPI, critical thinking, philosophical inquiry, and question formation improved significantly after the implementation while no improvement was observed in cognitive skills at this level.

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Considering the findings of the CTSPI and its sub-dimensions, pre-test scores of the students in the experimental and control groups presented in Table 5, it is understood that the students in the groups are statistically equal in terms of the CTSPI before the study.

Table 5. The Mann-Whitney U test findings related to the pre-test scores from the CTSPI and its sub-dimensions

Measurement Tools	**Groups**	**N**	**Sum of Ranks**	**Mean Rank**	**U**	**z**	**p**
The Philosophical Inquiry Sub-Dimension Pre-test	Experimental Control	14 13	202.500 175.500	14.464 13.500	84.500	-.315	.752
Cognitive Skills Sub-dimension Pre-test and Post-test	Experimental Control	14 13	225.500 152.500	16.107 11.730	61.500	-1.447	.140
Inquiry, Question Formation Skills Sub-dimensions Pre-test	Experimental Control	14 13	209.000 169.000	14.928 13.000	78.000	-.651	.515
The CTSPI Pre-test	Experimental Control	14 13	209.500 168.500	14.964 12.961	77.500	-.656	.512

*p<.05

Table 6. The Mann-Whitney U test findings related to the post-test scores from the CTSPI and its sub-dimensions

Measurement Tools	**Groups**	**N**	**Sum of Ranks**	**Mean Rank**	**U**	**z**	**p**
The Philosophical Inquiry Sub-Dimension Pre-test	Experimental Control	14 13	260.000 118.000	18.571 9.076	27.000	-3.135	.001*
Cognitive Skills Sub-dimension Pre-test and Post-test	Experimental Control	14 13	267.000 111.000	19.071 8.538	27.000	-3.510	.000*
Inquiry, Question Formation Skills Sub-dimensions Pre-test	Experimental Control	14 13	237.500 140.500	16.964 10.807	49.500	-2.117	.034*
The CTSPI Pre-test	Experimental Control	14 13	284.500 93.500	20.321 7.192	2.500	-4.302	.000*

*p<.05

Table 6 reveals that there is a statistically significant difference (p<.05) between the post-test scores of the students in the experimental and control groups in the CTSPI and its sub-dimensions (philosophical inquiry, cognitive, and question-formation skills). Accordingly, it can be stated that the students in the experimental group improved their philosophical inquiry, cognitive, and question-formation skills, and thus their critical thinking skills, significantly more than the students in the control group.

Table 7. Findings regarding the levels of the study groups according to the pre-test and post-test average scores in the CTSPI and its sub-dimensions

Groups	**Philosophical Inquiry**			**Language and Cognitive Skills**			**Question Formation**			**The CTSPI Total Score**		
	Mean	**Value**	**Criteria**	**Mean**	**Value**	**Criteria**	**Mean**	**Value**	**Criteria**	**Mean**	**Value**	**Criteria**
Exp. Pre-test	61.3	**M**		60.4	**M**		18.7	**M**		140.5	**M**	
Post-test	78.2	**H**	**L**:18-36	72.9	**H**	**L**:15-30	21.5	**H**	**L**:5-10	172.9	**H**	**L**:38-76
Cont. Pre-test	58.8	**M**	**M**:37-72 **H**:73-90	56.6	**M**	**M**:31-60 **H**:61-75	17.3	**M**	**M**:11-20 **H**:21-25	132.7	**M**	M:77-152 H:153-190
Post-test	65.3	**M**		58.8	**M**		19.1	**M**		142.5	**H**	

L: Low level**, M:** Moderate level**, H:** High level

Due to the nature of the CTSPI, it offers the opportunity to rate the participants at 3 levels (low, moderate, high) according to the average scores obtained from the measurement tool and its sub-dimensions. Table 7 created using this feature of the measurement tool reveals that the experimental group's pre-test average scores are at M (medium) level, and the post-test average scores are at H (high) level. On the other hand, it is seen that the pre-test and post-test average scores of the control group are both at M (moderate) level. In this context, although the level of the experimental group in terms of critical thinking and skills in the sub-dimensions increased after the implementation, the aforementioned skills of the control group remained at approximately the same level.

Table 8. Paired-sample t-test findings on the POE observation form of the control group pre-post-test scores

Groups	Measurement	N	Mean	Std.Dev.	df	t	p	d
Control	Prediction Pre-test	13	4.31	1.797	12	1.889	.083	.523
	Prediction Post-test	13	5.08	1.285				
	Observation Pre-test	13	5.38	2.631	12	.618	.548	.171
	Observation Post-test	13	5.05	1.121				
	Explanation Pre-test	13	4.15	2.230	12	.780	.451	.125
	Explanation Post-test	13	4.59	.818				
	The POE Pre-test	13	13.85	3.955	12	1.036	.321	.086
	The POE Post-test	13	14.72	1.677				

d: Effect size, p<.05

Table 8 reveals that there is no statistically significant difference between the pre-test and post-test scores of the students in the control group (p>.05), and the effect size of the differentiation is very low (d = .086 - .523) (Green, Salkind, & Akey, 2005). In this context, it is observed that the POE and skills of the control group students in the sub-dimensions did not show a statistically significant improvement before and after the implementation.

Table 9. Paired-sample t-test findings on the POE observation form of the experimental group pre-post-test scores

Groups	Measurement	N	Mean	Std.Dev.	df	t	p	d
Experimental	Prediction Pre-test	14	4.71	2.301	13	6.810	.000	**1.625**
	Prediction Post-test	14	7.31	1.136				
	Observation Pre-test	14	5.43	2.533	13	3.820	.002	**1.021**
	Observation Post-test	14	7.57	.800				
	Explanation Pre-test	14	3.86	2.282	13	4.193	.001	**1.120**
	Explanation Post-test	14	6.17	1.115				
	The POE Pre-test	14	14.00	4.772	13	6.914	.000	**1.848**
	The POE Post-test	14	21.05	1.563				

d: Effect size, p<.05

Table 9 reveals that experimental group students' pre-test and post-test scores of the POE and its sub-dimensions (prediction, observation, and explanation) have a significant difference (p<.05), and this difference is positive in favor of the post-tests. On the other hand, it is seen that the effect size of this differentiation (d=1.021-1.848) is high. This may be due to the effect of the POE on the prediction, observation, explanation, and POE skills of the experimental group students.

The results of the statistical operations performed on the scores obtained by the study groups before and after the implementation from the POE observation form and its sub-dimensions are presented below. The Levene test, which is prerequisite for the MANOVA, was conducted for the POE pre-test scores of the study groups, and as a result of the analysis, it was understood that the POE form and its sub-dimensions of the groups provided the homogeneity of the variances, which is prerequisite for the MANOVA, (p>.05).

Table 10. Findings obtained from the MANOVA regarding the POE form pre-test scores

Effect	Wilks λ	F	Hypothesis Sd	Error Sd	p	η^2
Group	.983	.127	3.000	23.00	.943	.16

p<.05, Effect: Wilks' Lambda

The findings for the hypothesis test presented in Table 10 reveal that there is no significant difference between the groups (Wilks λ=.983, p=.943). Accordingly, the POE form of the groups is equal in terms of pre-test scores and the H_0 hypothesis is valid.

Table 11 reveals that there is no significant difference between the scores of the groups obtained from the POE form and its sub-dimensions before the implementation (p=.615 -.965) and the effective value of the grouping process (η^2=.000 -.005) is very low. Accordingly, it can be stated that the students in the experimental and control groups are equal in terms of the features examined in the POE form and its sub-dimensions before the implementation.

Table 11. Findings obtained from the MANOVA regarding the pre-test scores of the groups on the POE form

Dependent Variable-Source		Mean	Sum of Squares	df	Mean Square	F	p	η^2
Prediction Pre-test	Experimental	4.71	1.114	1	1.114	.259	.615	.010
	Control	4.31						
Observation Pre-test	Experimental	5.43	.013	1	.013	.002	.965	.000
	Control	5.38						
Explanation Pre-test	Experimental	3.86	.593	1	.593	.116	.736	.005
	Control	4.15						
The POE Pre-test	Experimental	14.00	.016	1	.016	.008	.928	.000
	Control	13.85						

The Levene test, which is a prerequisite for the MANOVA test, was performed on the post-test scores obtained from the POE form and its sub-dimensions, as in the POE Pre-test scores, and it was understood that the POE post-test scores of the study groups provided the homogeneity of the variances (p>.05).

Table 12. Findings obtained from the MANOVA regarding the POE form post-test scores

Effect	Wilks λ	F	Hypothesis Sd	Error Sd	p	η^2
Group	.192	32.259	3.000	23.00	.000	.808

p<.05, Effect: Wilks' Lambda

The findings presented in Table 12 reveals that the hypothesis test for the post-test scores of the POE form and its sub-dimensions of the study groups show a significant difference (p=.000) and the effect size of the difference is high (η^2=.808). Accordingly, it is understood that the groups are not equal in terms of their post-test scores. The results of the MANOVA conducted to determine the level of differentiation in the post-test scores of the groups are presented in Table 13.

Table 13. Findings obtained from the MANOVA regarding the post-test scores of the groups obtained from the POE form

Dependent Variable	Source	Mean	df	Mean Square	F	p	η^2
Prediction Pos-test	Experimental	7.310	1	33.599	22.962	.000	.479
	Control	5.077					
Observation Post-test	Experimental	7.571	1	42.811	45.750	.000	.647
	Control	5.051					
Explanation Post-test	Experimental	6.167	1	16.762	17.316	.000	.409
	Control	4.590					
The POE Post-test	Experimental	21.048	1	270.066	103.095	.000	.805
	Control	14.718					

The findings related to the POE form post-test scores of the study groups in Table 13 reveals that there is a significant difference between the post-test scores of the POE and its sub-dimensions of the study groups (p=.000 for all sub-dimensions) and the effective value of differentiation is high for all sub-dimensions (η^2=.409 - .805). The post-test average scores of the groups from the sub-dimensions reveal that in all sub-dimensions, the experimental group post-test average scores (Mean=7.310, 7.571, 6.167, 21.048) are higher than the control group post-test average scores (Mean=5.077, 5.051, 4.590, 14.718). In this context, it is understood that the significant difference between the groups with a high effective value, is in favor of the experimental group.

During the implementation process (from the 1st to the 6th implementation), the scores of prediction, observation, and explanation skills obtained from the POE form obtained by the students in the study groups were transferred to the graphs to examine the development of the students' skills throughout the process.

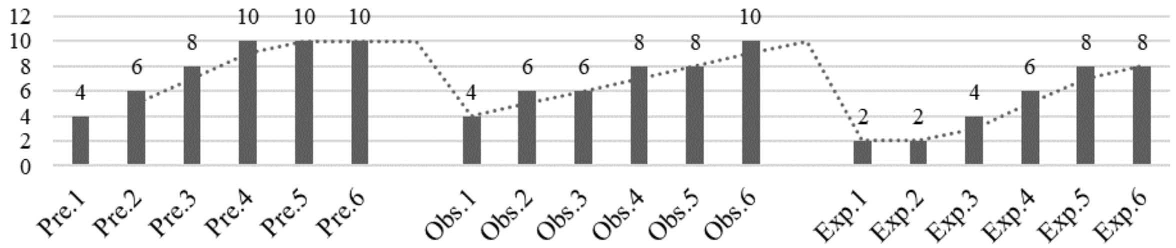

Figure 3. Column chart showing the change of experimental group students' average POE scores throughout the implementation process

The chart in Figure 3 highlights that the scores of prediction and observation skills of the students in the experimental group were at an acceptable level ($\bar{x}$=4) at the beginning of the implementation, increased linearly throughout the implementation, and increased to a very good level ($\bar{x}$=10) at the end of the implementation. Similarly, it is understood that the explanation skill scores of the students in this group were low ($\bar{x}$=2) at the beginning of the implementation, increased linearly throughout the implementation, and increased to a good level ($\bar{x}$=8) at the end of the implementation. On the other hand, considering the classification made in scientific process skills, POE skills can be listed from simple to advance as prediction<observation<explanation. In this context, the data in the chart reveal that students' basic skills such as prediction and observation were relatively higher at the beginning of the implementation, the improvement throughout the implementation was at a higher level, and higher-order skills such as explanation increased linearly like other skills at the beginning of the implementation but did not increase to a very good level.

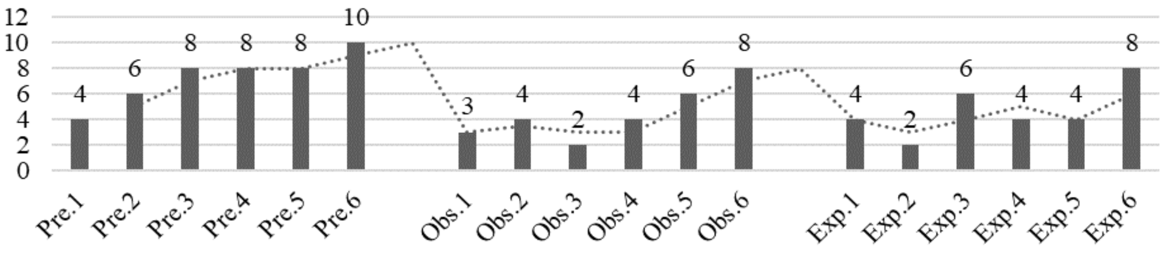

Figure 4. Column chart showing the change of ontrol group students' average POE scores throughout the implementation process

The chart in Figure 4 includes the average scores of the students in the control group regarding the prediction, observation, and explanation skills obtained from the POE form throughout the implementation. The chart reveals that at the beginning of the implementation, the average scores of the control group students' ability to make predictions were at an acceptable level ($\bar{x}$=4) and increased to a very good level with a linear increase during the application process. Similarly, the average scores of the observation skills of the students were at an acceptable level ($\bar{x}$=3), increased relatively linearly throughout the implementation, and increased to a good level ($\bar{x}$=8) at the end of the implementation. On the other hand, it can be said that the average scores of the students' explanation skills were at an acceptable level ($\bar{x}$=3) at the beginning of the implementation with a fluctuating increase throughout the implementation and increased to a good level ($\bar{x}$=8) at the end of the implementation.

Considering the change in average scores of these skills, one may notice that as the level of development of skills increases (prediction<observation<explanation), the increase in average scores slows down and the linear increasing trend deteriorates.

The findings obtained from the interviews with 2 teachers and 1 science expert who participated in the experimental group as observers are presented below.

The teachers as external observers responded to the question below as follows:

Q_1: "Did you find the method effective? Why?"

T_1: "I find the method effective enough to be used not only for science subjects but also for all subjects, for example, teaching traffic rules on a social issue or teaching daily maintenance skills. In other words, while teaching traffic rules, traffic rules can be taught by showing the accidents and using the POE. Furthermore, the importance of washing hands before and after meals can be taught. I also prepare and use the method based on games."

T_2: "The method is really effective. The attention of the students was slightly less distracted than before. While we make it based on a game, they often get out of the game in a very short time. However, they focused their attention much longer in the experiments. At first, they saw it as a game, and then as they discovered, they attended events more interested, especially to get their predictions right. They responded with excitement and enthusiasm while making explanations. Only those who predicted wrong got a little upset. It is much more effective and instructive than gamification. They continued to talk to each other after we left anyway. I observed such things. So I found it effective. It also suits their levels. It just took more time, that's all."

Q_2: "Would you like to use the method later? Why?"

T_1: "I definitely use it because the method can also be used as a game. Seeing that children make such explanations, defend their own ideas, make their observations, or predictions such as "I saw it this way, it should be like this, I predicted it correctly" shows that they really gained scientific skills. At first, I was skeptical, but especially after the second experiment, I saw the difference. At the end of the activities like games, they never talked about the subject and care about different things before, but they were influenced by these, and then they continued to talk."

T_2: "I will use it, though not very often because it is necessary to prepare content and so on. But the method is really effective and useful. I use myself."

The statements given by the teachers regarding the interview questions reveal that they find the POE effective and useful and more efficient than gamification in ensuring that students focus and develop scientific skills, adding that the POE can be used effectively in fields other than science.

The science expert who participated in the study as an external observer in the experimental group answered the questions as follows.

Q_1: "Did you find the method suitable for the level of the students?"

"The method is fitted for the levels of the students, but the guide or implementer should manage the process well as kids can get bored. However, they hardly ever got bored and distracted for 6 weeks throughout the implementation. Especially after the second experiment, they adapted better. Later on, they made much better predictions, observations, and explanations. Their prediction skills and their ability to express sentences improved noticeably throughout the process. I saw 4 students repeat themselves several times not to forget their observations. It could have been much more successful with fewer students, for instance, 5-6 students would be enough. But POE skills improved significantly over the period. Especially in the 5th and 6th experiments, they explained topics very well. They more often used such things as "I saw that, so that should be the answer, etc." The effects of the method should be tested outside of science subjects, that is, social issues such as basic development skills. That is all I will say."

Q_2: "Did you find the content created by the science teacher suitable for the level of the students?"

"The experiments were well-selected. At first, I thought that the experiments were successful because they were good and I asked the teachers if they were doing experiments. I saw the experiments they had done. Earlier experiments sounded more interesting, these were little more scientific. But when you use the method in this way, I mean, step by step the contents were quite suitable. After the 4th experiment, 15 minutes after the implementation was completed, I asked the children about the experiment. I got very positive answers. One of the teachers said they started acting in games just like they did in experiments. They used expressions such as "this is because", or "because of that". I think it is necessary to adjust the level well while preparing the content."

Considering the responses of the science expert to the questions, one may notice that s/he considers the POE as a method that can be used by students at this level, increases their attention, and can be effective in the development of POE skills. On the other hand, it is also understood that s/he is of the opinion that in the implementation of the method, the teacher should have the ability to use the method

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effectively, and that the contents were suitable for the levels of the students and more remarkable than gamification with the POE.

The interpretation of the findings obtained from the research, comparison with the literature, and the results obtained are discussed next.

DISCUSSION and CONCLUSION

In addition to basic skills such as self-care and speaking, higher-order skills such as inquiry, critical thinking, scientific thinking, and scientific process develop in individuals in early childhood (Jacobson & Bergman, 1980). In this context, it can be said that teaching methods that will enable the development of high-level skills of students should be used in pre-school education. This study was designed to determine the effect of the POE on students' critical thinking and POE skills in early childhood, and important findings were obtained.

The findings of the study reveal that the experiments conducted using the POE are more effective in the development of all skills of the students in the CTSPI and its sub-dimensions than gamification, and the skills that are initially at the intermediate level have been developed to a higher level. It was observed in the implementation process that students did not sufficiently inquire about the content offered to them and did not focus on problem situations as they perceive activities of gamification as a game. The students were better-focused through the POE while watching the videos that reflect the problem situation. It is also thought that students had an increased tendency of inquiry and critical approach when they were told that the questions asked by the teacher to recognize the problem situation before the prediction process would be recorded and compared with the result to be achieved at the end of the process. Similarly, during the observation process (the stage of experiments), the experiments carried out under the guidance of the researcher along with guiding and thought-provoking questions during the process contributed to the students' critical approach to the subject throughout the process.

On the other hand, although gamification is not effective in the linguistic-cognitive skills of the students, the POE is highly effective in these skills (Table 6). It is believed that this is because students were asked to make explanations based on the observation process during the explanation process, which is the last stage of the POE, and guided with questions that would allow them to discuss their observations. Similar results were obtained in the study that focused on the effect of the philosophical teaching program conducted in 2018 on the CTSPI in early childhood by Karadağ & Demirtaş, who reached the conclusion that the philosophical teaching program in early childhood affects the development of the students' skills in CTSPI and its sub-dimensions.

Another remarkable finding is that the POE-based implementations are more effective in the development of the students' prediction, observation, and explanation skills than gamification and that gamification does not significantly affect the development of the students' prediction, observation, and explanation skills, whereas the POE has a high degree of effect on students' prediction, observation, and explanation skills while also improving these skills to a very good level. On the other hand, it is understood that the POE creates a linear continuous increase in the development of these skills while gamification has a fluctuating (decreasing-increasing) effect on the development of these skills.

The POE was observed to allow for a better and effective implementation of prediction, observation, and explanation, to motivate students to make predictions, observations, and explanations, and to allow guiding these stages with scientific questions. It can be argued that the POE has both a linear and stable contribution to the development of the aforementioned skills, and its high effective value is due to the above-mentioned issues. On the other hand, the students perceive the activities of gamification only as entertainment and therefore fail to make the best use of the process efficiently. The low level and indefinite change in gamification are also due to the above-mentioned issues. The findings of the study by Hsu et al. (2011) on pre-school students support the findings of this study, and researchers report that POE implementations supported by computer games increased students' conceptual understanding of the concept of shadow.

Teachers participating in the study as external observers are experienced educators, who have a seniority of 10 years, have taken care of the students in the study group for 2 years, and thus get to know the students closely. External observers stated that apart from being interesting and motivating in these age groups; the POE can be used in transferring socio-scientific issues other than science. It is believed that the motivation of the students is enhanced if proper management of what/why/how questions through the POE is ensured, if small rewards are given where their predictions are correct, and if students are encouraged to discuss during the explanation process. On the other hand, the teachers also point out that the presentation of socio-scientific issues with gamification does not have enough effect since students perceive the process as a game and cannot reflect such information in reality. Yet, the POE allows students to observe the events in the context of cause-effect relationships and to explain them with their own expressions through mental processing, thus, leading teachers to think that the POE would be more effective in understanding socio-scientific issues.

It can be concluded that POE-based activities are more effective than gamification (traditional practices) in the development of the students' higher-order skills such as critical thinking and the POE in early childhood and that the POE not only improves basic scientific skills and critical thinking skills and students' speaking and discussion skills in these age groups but also is helps attract the attention of the students during lesson and motivates them. On the other hand, it is understood that the teachers see the POE as an effective method that can be used not only in science but also in teaching socio-scientific subjects. Finally, according to the science experts, the POE is suitable for the levels of the students in this age group, and knowing the features of the method and proper management may facilitate revealing the superior aspects of the method.

Based on the findings, the following recommendations may be suggested:

Pre-school teachers can use the POE while teaching scientific and socio-scientific subjects and employ the POE more in pre-school education programs. Research on the effects of the POE on the teaching processes carried out with large groups and to determine the effect of the POE on students' different skills (analytical thinking, reasoning, scientific discussion, etc.) in early childhood is likely to make significant contributions to the literature.

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