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EXPLORING THE EFFECTS ON FIFTH GRADERS' CONCEPT ACHIEVEMENT AND SCIENTIFIC EPISTEMOLOGICAL BELIEFS: APPLYING THE PREDICTION-OBSERVATION-EXPLANATION INQUIRY-BASED LEARNING MODEL IN SCIENCE EDUCATION

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Abstract. *The inquiry-based learning model can facilitate students' understanding of scientific concepts. Scientific epistemological beliefs (SEBs) are related to students' beliefs about the nature of the process of knowledge in science education. However, whether the "prediction-observation-explanation" (POE) inquiry-based learning model can facilitate fifth graders' concept achievement and SEBs in science education has not been extensively studied. This study selected the unit of Light Refraction to explore the effects of POE learning on fifth graders' science concept achievement and SEBs. The Light Refraction Test and Scientific Epistemological Beliefs measurement were applied to the two groups prior to and following the experiment. The experimental group (N=86) participated in POE inquiry-based learning, whereas the control group (N=88) participated without POE inquiry-based learning. The results revealed a significant difference between the two groups, with the experimental group learners performing better than the control group in the concept achievement. In addition, the results showed better positive effects of POE on experimental group learners' SEBs in the scales of Source and Certainty. Findings suggested that learners achieved better concept achievements and SEBs with the approach of POE inquiry-based learning, which pointed to certain implications for inquiry-based teaching, as well as in education of future science instructors.*
Keywords: *inquiry-based learning model, light refraction, prediction-observation-explanation, science education, scientific epistemological beliefs*

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Introduction

Cultivating the literacy of science has become the main goal in Chinese science education. Özdem (2010) indicated that scientific concept knowledge was one of the important evaluation indicators for scientific literacy, while there has been increasing support for inquiry-based learning as a practical method to develop science learning and improve learners' scientific literacy (Firman et al., 2019; Suarez et al., 2018). For example, Özgür and Yılmaz (2017) studied students' learning of the Acids-bases concepts and showed that inquiry-based learning was a usable approach to improve students' achievement. The Cairns and Areepattamannil (2019) study did show some positive results for dispositions towards science such as science self-concept; however, the results also revealed that inquiry science teaching and science achievement has had a significantly negative correlation. Considering the inconsistent results, it is necessary to study whether the approach of inquiry-based serves science achievement in the different inquiry approaches. Accordingly, this study took POE (Prediction-Observation-Explanation) as the inquiry science learning model, as it has been proven to be a strongly way to learn physical sciences (Latifah et al., 2019). For example, Bunprom et al. (2019) showed that the POE learning strategy helped to overcome eleventh graders' misconceptions of temperature and heat materials. Çalık and Bayçelebi (2020) found that an intervention using the POE learning strategy stimulated fifth graders' conceptions and awareness of healthy nutrition. However, a lack of such an intervention study at the level of fifth grader for learning the concept of light refraction calls for the current study. Whether the POE inquiry learning strategy will also promote the conceptual learning of light refraction for fifth graders remains to be seen. In this study, how POE affects fifth graders' concept achievement while they are involved in learning light refraction was explored.

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Mason and Bromme (2010) defined epistemological beliefs (EB) as "individual representations about knowledge and knowing" (p. 1). EBs was considered to be a crucial factor in interpreting information and knowledge and was therefore related to learners' conceptual understanding during the learning process (Songer & Linn, 1991). Peffer and Ramezani (2019) emphasized the importance of exploring the effects of different teaching methods on scientific epistemological beliefs (SEBs). In the field of educational research, SEBs have been the focus of various science learning studies (Kampa et al., 2016). For example, Liang and Tsai (2010) have stated that learners' SEBs might have an impact on science concept learning, science learning strategy selection (Hsu et al., 2014), and other learning behaviors (Lin et al., 2013). Accordingly, increasing attention has been paid to the impacts of inquiry-based teaching on learners' SEBs. For example, Yang et al. (2019) studied the impacts of the web-based inquiry learning model on SEBs and found that it was beneficial for eighth grader to predict their knowledge integration performance. However, few studies have considered the impacts of applying the POE inquiry-based learning model to the SEBs of children, indicating that research on the SEBs of children was necessary (Zhou et al., 2019). Thus, how POE can activate or deactivate fifth graders' SEBs in learning science was of interest in this study.

According to the cognitive theory of multimedia learning (Mayer, 2014), learning is an active process of filtering, selecting, organizing, and integrating information based on one's prior knowledge. Mayer's CTML presented the learning model in which the brain interprets learning material via a logical mental construction process. In line with this process, this study presented an inquiry-based science learning model, POE, to explore the effects on fifth graders' concept achievements in the Light Refraction unit, and on their SEBs.

Literature Review

Inquiry-Based Learning

The concept of inquiry has a long history in the public school system. Using an inquiry approach to teach science has been emphasized (Gillies & Rafter, 2020). Ketpichainarong et al. (2010) stated the inquiry-based learning refers to the pedagogical strategies that take scientific inquiry and use general processes as the methodology of teaching and learning; it emphasizes students asking questions, investigating, and solving problems. However, the inquiry has many meanings and interpretations, as Cairns and Areepattamannil (2019) discussed. For example, Annisa and Rohaeti (2018) pointed out that inquiry-based learning was an approach that involves asking questions, seeking information, and discovering new ideas that were relevant to an event.

There were many inquiry-based learning models and various inquiry models which had different effects on science learning (Hong et al., 2019). Different inquiry-based learning models facilitated students' understanding of scientific concepts differently (Rakkapao et al., 2014; Bumbacher et al., 2018). Jerrim et al. (2020) found that using inquiry-based teaching was frequently not related to a better science achievement. In other studies, students who frequently experienced inquiry-learning approaches in science courses showed lower levels of science achievement (Areepattamannil et al., 2020; Firman et al., 2019; Özgür & Yılmaz, 2017; Sarwi et al., 2019; Suarez et al., 2018). However, using different inquiry-based models yields different learning results. For example, the POE inquiry-based model is a potential way to promote students' acquisition of conceptions (Hong et al., 2014; Bednar et al., 1992). The study of Arsy et al. (2019) showed that implementing the POE learning strategy with the Group Investigation model was beneficial for training students to discover new knowledge, to improve the achievement and the quality of their learning. However, there was no particular study focused on using POE to explore children's concept achievement in the area of Light Refraction.

The POE Inquiry-Based Learning Model

Pegg (2006) divided the inquiry-based learning model into three categories as follows: a) POCPE model involving the phases of prediction, observation, data collection, and explanation; b) POE model involving the phases of prediction, observation, and explanation; and c) PCMGE model involving the phases of prediction, data collection, measurement, graph making, and explanation. Compared to the other two inquiry-based learning models, POE was a more simplified version. In the POE model, the steps are as follows: a) present the students with a situation; b) ask them to predict about what will happen when changes are made; c) ask for their reasons for their prediction; d) have them perform the change and make observations; and e) have them try to make

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consistent with any conflict between their predictions and observations (Gunstone, 1990). It was common for inquiry-based learning to be arranged into inquiry stages, which were combined to form an inquiry model (Pedaste et al., 2015). A number of different POE inquiry phases and models have been described; they enabled students to connect knew knowledge with their prior knowledge, and helped them absorb the knowledge (e.g., Mamun et al., 2020; Hong et al., 2019). Particularly, Coştu et al. (2012) showed that the teaching strategy of POE-based promoted learners' achievement. Hong et al. (2014) designed learning activities based on the POE inquiry learning model and found that it enhanced students' interest in the topic and their intention to continue to learn science.

Research studies had found that the POE inquiry learning approach contributed to learners' conceptual understanding and learning science (e.g., Arsy et al., 2019; Ayvacı, 2013; Banawi et al., 2019; Chen et al., 2020; Hong et al., 2014; Jasdilla et al., 2018). For example, Chen et al. (2020) implemented the POE strategy in a science inquiry study and proved that POE promoted students' conceptual change and science learning. In addition, Jasdilla et al. (2018) tested the POE strategy, and their results showed that it had effects on fifth-grade students' mental models in science learning. Moreover, the study of Ayvacı (2013) implemented POE inquiry learning with a group of science teachers and concluded that it was effective and attractive for learning scientific concepts. This study focused on how POE could be applied to Light Refraction learning in a science classroom.

Scientific Epistemological Beliefs

William Perry was the first to study epistemological beliefs in learning (1970). His study aimed to better grasp how students interpreted their educational experiences. Epistemological beliefs refer to beliefs about the nature of knowledge and the process of knowing (Hofer & Pintrich, 1997). Hofer and Pintrich (1997) suggested epistemological beliefs consisted of four dimensions, where the "certainty of knowledge" dimension and the "simplicity of knowledge" dimension address the nature of knowledge, while the "source of knowing" dimension and the "justification of knowing" dimension concern the nature of knowing. Hofer and Pintrich's epistemological beliefs theories provided the foundation upon which later research on individuals' epistemological beliefs has been based. For example, based on Hofer's (2000) works, Conley et al. (2004) suggested that the elementary students' scientific epistemic beliefs should be divided into four dimensions. The four dimensions were "source" (e.g., authority or experts are the only source of science knowledge), "certainty" (e.g., there is only one right answer regarding science knowledge), "development" (e.g., science knowledge is a subject of constant development and change), and "justification" (e.g., evidence from different experiments builds the science knowledge), respectively.

Many studies have shown that epistemological beliefs promoted scientific learning (Areepattamannil et al., 2020). She et al.'s (2019) study indicated that epistemological beliefs about science are the most powerful predictors of learners' scientific literacy performance. In Yang et al.'s (2019) study, they examined the effects of the web-based inquiry learning model on SEBs. However, few studies have explored how POE inquiry learning affects children's SEBs; thus, the present study paid attention to the influence of inquiry-based Light Refraction teaching on students' SEBs.

Research Questions

From the results of the several studies described above, there were many benefits to POE. This approach which the teacher incorporated was implemented to assist learners in finding their own knowledge and improving learning quality. However, none of the previous studies in the POE inquiry learning strategy have tested Light Refraction. Moreover, few studies have analyzed the effect on the concept achievements and SEBs of fifth graders when implementing POE learning-based teaching. Therefore, the current study explored the effects of the POE inquiry-based learning model on fifth graders' concept achievement in the unit of Light Refraction and their SEBs, with the aim of answering the following research questions:

1. What are the effects of the POE inquiry-based learning model on fifth graders' concept achievement in Light Refraction?
2. What are the effects of the POE inquiry-based learning model on fifth graders' SEBs in Light Refraction?

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Research Methodology

General Background

In this study, the experiment with pre-test and post-test design was adopted. As shown in Table 1, the control and experimental groups were tested by the Light Refraction Test (LRT) and Scientific Epistemological Beliefs measurement (SEBs), before and after the experiment. The experimental group participated in POE inquiry-based learning, while the control group did not. The study was implemented with fifth graders at a primary school in Jiangsu, China in the fall semester of 2020-2021. The same male science teacher, with 15 years of experience in science teaching, taught all control and experimental groups, and the groups were provided with identical content of Light Refraction.

Table 1
Research Design

Group	Pre-test	Treatment	Post-test
Control	LRT & SEBs	POE inquiry model	LRT & SEBs
Experimental	LRT & SEBs	Conventional	LRT & SEBs

Sample

The research sample was taken from four classes, with a total of 174 fifth grade students, all aged approximately 11 years old. Two classes (46 boys and 40 girls) as the experimental group participated in the POE inquiry learning teaching and the other two classes (45 boys and 43 girls) as the control group participated without the POE inquiry learning. The questionnaire was issued in November 2020, and a total of 174 questionnaires were collected. Randomly filled questionnaires were recorded as invalid. After deleting 23 invalid questionnaires, 151 questionnaires, including 70 from the experimental group (52.9% boys; 47.1% girls) and 81 from the control group (50.6% boys; 49.4% girls), were used for analysis in this study. This study followed the ethical guidelines provided by The Nanjing Normal University of China Human Research Ethics Committee. All participants were completely voluntary, and expressly informed consent, including the privacy measures necessary to protect their privacy interests. In addition, participants were informed that these tests would be used for this research purpose only and free to withdraw at any stage.

Instrument

The Light Refraction Test (LRT)

In science education of Chinese fifth graders, the unit of Light Refraction is taught in the fifth grade. It is important for their future study that students acquire the concept of Light Refraction properly at that age.

The Light Refraction Test was used to measure the fifth graders' concept achievement of Light Refraction both before and after the treatment. Yang et al. (2008) suggested that the design of tests should be based on the science curriculum and teaching objectives. The test of this study mainly assessed the Light Refraction achievement in the basic concepts of Light Refraction. It consisted of five multiple-choice questions and four true-or-false items. One item was marked as one point. One sample of a multiple-choice question was: "Which of the following does not apply the convex lens principle?" And the choices were presbyopic glasses, magnifying glass, and rearview mirror. One sample of a true-or-false item was: "A convex lens can make an object look like an inverted image on a screen, whereas a concave lens cannot." The same questions were applied to the pre-test and post-test, but the order differed. A panel of three science teachers determined the face validity and clarity of each test item. They also analyzed the relationship between the LRT items and the teaching objectives and verified that the LRT instrument had good content validity and measured construct validity, which was suitable for the participating students.

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Scientific Epistemological Beliefs Measurement

A measurement tool that was frequently utilized to evaluate students' SEBs was the Conley et al.'s (2004) questionnaire. This questionnaire contained four subscales and 26 items. The work by Tsai et al. (2011) translated Conley et al.'s SEBs questionnaire into Chinese and validated this questionnaire by surveying students' SEBs. This study revised this Chinese version questionnaire developed by Tsai and adopted a 5-point Likert scale where 1 represents strongly disagree and 5 represents strongly agree. After exploratory factor analysis, six items (two from "source", two from "certainty", one from "development" and one from "justification") were deleted. The revised SEBs measurement's KMO was .742, and Bartlett $p < .05$, indicating that it was suitable for the fifth graders. The overall alpha value was .88, and the four subscales of SEBs' alpha values were above .70 (ranged from .76 to .89). The instrument was therefore considered to be reliable enough to evaluate the fifth graders' SEBs. Detailed descriptions of each of the four subscales (20 items) as well as example items are provided below:

- Source (3 items): Assessing students' beliefs about external authorities and experts as the only source of scientific knowledge. Example item: "In science, you must believe everything you read from the science books" (scored in reverse).
- Certainty (4 items): Reflected students' beliefs in the right answer to knowledge in science. Example item: "Finding the right answer is the most important part of scientific research" (scored in reverse).
- Development (6 items): Assessed students' beliefs about science as a subject that is constantly evolving and changing. Example item: "Some scientific ideas today are different from what scientists used to consider."
- Justification (7 items): Reflected students' beliefs about the role of scientific experiments in science and how they justify scientific knowledge. Example item: "Curiosity and thinking about how things work lead to ideas about science experiments."

Design of a POE Inquiry-Based Learning Model for Light Refraction

The POE learning model was an approach of promoting interest in science courses (Karamustafaoğlu & Mamlok-Naaman, 2015). Pegg (2006) divided the inquiry-based learning model into three categories. In this study, the model 2 involving the phases of prediction, observation, and explanation was applied to Light Refraction to help the students understand the concepts. In this study, the POE learning involved three rounds. Round 1 provided the students with a glass of water and a pen, round 2 with a convex lens and round 3 with a concave lens. Each round of the three phases of "prediction, observation and explanation" are listed as follows and are illustrated in Figure 1.

Prediction 1: Posed a question to guess (3 minutes). The teacher presented a glass of water and a pencil. The question was: After you put a pencil into water, what happens when looking from the top and the side? The students predicted the answers based on their prior knowledge and gave their reasons for the prediction. In this phase, the students were asked questions as a way of promoting their interest and motivation. They did not know whether their answers were right or wrong.

Observation 1: Explored and observed phenomena (20 minutes). A group of students was given a pen and a glass of water; they put the pen into the water, then observed, discussed, and recorded the phenomenon. During this stage, the teacher facilitated their investigation by providing them with books, giving them directions, asking them questions, and encouraging them to explore and observe.

Explanation 1: Answered and explained (17 minutes). After exploring and observing phenomena, the students explained the phenomenon of the pencil looking bent after being put into a glass of water. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted students in finding that traveling from one transparent object to another, light's direction of travel bends at the interface. The teacher helped them to understand the phenomenon of a pen in water and the concept of Light Refraction.

Prediction 2: Posed a question to guess (3 minutes). The teacher presented a convex lens. The question was: What are the shape and imaging features of a convex lens? The students predicted the answers based on their prior knowledge and gave reasons for their prediction.

Observation 2: Explored and observed phenomena (10 minutes). Every student was provided with a convex lens to find reasons for their predictions and performed observations. In this stage, a group of students used a convex lens to observe a tree, which required them to collect their own data about convex lenses and the features of light passing through a convex lens, and to explore and observe certain phenomena.

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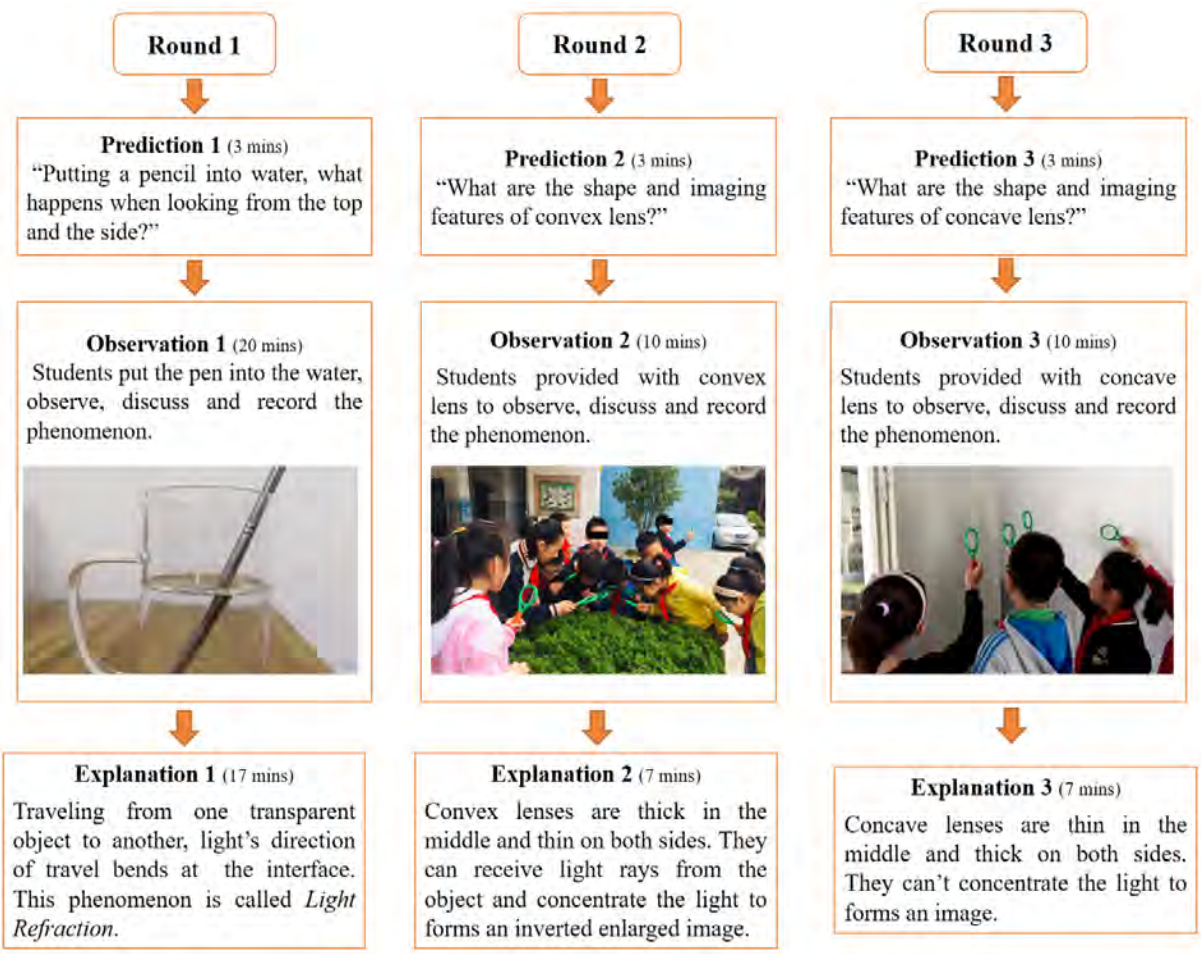
Explanation 2: Answered and explained (7 minutes). After exploring and observing phenomena, the students explained the shape and imaging characteristics of a convex lens. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted the students in finding that convex lenses are thick in the middle and thin on both sides, and they can receive light rays from the object and concentrate the light to form an inverted enlarged image. In addition, the teacher helped them to link the concept of a pen in water and the imaging characteristics of a convex lens.

Prediction 3: Posed a question to guess (3 minutes). The teacher presented a concave lens. The question was: What are the shape and imaging features of concave lenses? The students predicted the answers based on their prior knowledge and gave their reasons for the prediction.

Observation 3: Explored and observed phenomena (10 minutes). Every student was provided with a concave lens to find reasons for their predictions and performed observations. In this stage, a group of students used a concave lens to observe the class door, which required them to collect their own data about concave lenses and the features of light passing through a concave lens, and to explore and observe certain phenomena.

Explanation 3: Answered and explained (7 minutes). After exploring and observing phenomena, the students explained the shape and imaging characteristics of a concave lens. In this stage, the students reported their observations to the whole class and to interpret their collective findings. The teacher assisted the students in finding that concave lenses are thin in the middle and thick on both sides, and they can receive light rays from the object, but cannot concentrate the light to form an image. In addition, the teacher helped them to link the concept of imaging features of convex lenses and concave lenses.

Figure 1
The POE Inquiry-Based Model (The Experimental Procedure)



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Procedure

This study was conducted over four 40-minute lessons. In lesson 1 (before the treatment), both groups of students took a pre-test. The LRT and SEBs questionnaires were administered to identify their lens conceptions knowledge, and to understand their SEBs, respectively. In lessons 2 to 3 (during the treatment), the control group participated in traditional teaching without lenses, at the beginning of which concepts related to Light Refraction were explained. The students then read about the content in their textbooks in the classroom, following which teacher conducted Light Refraction experiments based on the textbook. In contrast, the experimental group students performed experimental activities using the POE inquiry learning model. In lesson 2, the experimental group conducted the first round of POE. In lesson 3, the experimental group conducted a second and third round of POE. In lesson 4 (after the treatment), both groups took a post-test. The same instruments were used for all students to understand the effects of the treatment on their Light Refraction concept achievement and their SEBs.

Data Analysis

The pre-test and post-test learning achievement and SEBs data were carried out by SPSS (Statistical Package for the Social Sciences). Basic descriptive statistics (Number in a subsample *N*, mean *M*, standard deviation *SD*) of the numerical variables were determined. An independent sample *t* test was used to analyze the difference in the pre-test and post-test of the learning achievement, SEBs and four SEBs scales. In addition, the significance level of the independent sample *t* test in this research was set to $p = .05$.

Research Results

Concept Achievement of the Unit of Light Refraction

Table 2 shows the independent sample *t* test of the fifth graders learning achievement. No significant difference ($t = .592$, $p = .555$, effect size $d = .101$) was found between the two groups in the pre-test. However, in the post-test, there was a significant difference ($t = -3.835$, $p < .05$, effect size d = -.634) between the two groups. The post-test scores of the experimental group ($M = 6.89$, $SD = 1.246$) were higher than the control group ($M = 6.07$, $SD = 1.340$). The inquiry approach of POE used with the experimental group had more success in terms of promoting learning achievement compared to the traditional teaching.

Table 2
Independent Sample t Test Results of the Two Groups' Learning Achievement

	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Pre-test	Control	81	4.36	1.248	.592	149	.555	.101
	Experimental	70	4.24	1.122				
Post-test	Control	81	6.07	1.340	-3.835	149	< .05	-.634
	Experimental	70	6.89	1.246				

Students' Scientific Epistemological Beliefs

Table 3 shows the independent sample *t* test of the fifth graders' SEBs. As we can see for the two groups, the scores in post-test were higher than the pre-test. The pre-test results showed no significant difference between the two groups ($t = -.334$, $p = .731$, effect size $d = -.043$). However, in the post-test, there was a significant difference ($t = -3.676$, $p < .05$, effect size $d = -.609$) between the two groups. The average SEBs scores of the experimental group ($M = 3.47$, $SD = .294$) were higher than the control group ($M = 3.28$, $SD = .329$), indicating that the POE teaching which the experimental group received had more success in terms of promoting SEBs compared to the traditional teaching.

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Table 3
Independent Sample t Test Results of the Two Groups' SEBs

	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Pre-test	Control	81	3.09	.398	-.334	149	. 731	-.043
	Experimental	70	3.11	.530				
Post-test	Control	81	3.28	.329	-3.676	149	< .05	-.609
	Experimental	70	3.47	.294				

The independent sample *t* test was employed to analyze the pre-test of the four SEBs scales. Table 4 shows that the four scales of "Source" (t = -1.118, p = .276, effect size d = -.174), "Certainty" (t = 1.56, p = .121, effect size d = .252), "Development" (t = -0.175, p = .861, effect size d = -.037) and "Justification" (t = -1.188, p = .237, effect size d = -.187) showed no significant difference in the pre-test.

Table 4
Independent Sample t Test Results of the Items of the Two Groups' Pre-test SEBs

Item	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Source	Control	81	2.67	1.122	-1.118	144.39	.276	-.174
	Experimental	70	2.84	.806				
Certainly	Control	81	2.92	.783	1.56	149	.121	.252
	Experimental	70	2.70	.952				
Development	Control	81	3.72	.671	-.175	123.946	.861	-.037
	Experimental	70	3.75	.925				
Justification	Control	81	3.91	.481	-1.188	112.6	.237	-.187
	Experimental	70	4.03	.767				

The independent sample *t* test was employed to analyze the post-test of the four SEBs scales. In the post-test, Table 5 shows that there was a significant difference in the "Source" (t = -5.923, p < .05, effect size d = -.975) and "Certainty" (t = -2.914, p < .05, effect size d = -.463) scales between the experimental group and control group. The average SEBs score of the experimental group (M = 3.71, SD = .861) was significantly better than that of the control group (M = 2.95, SD = .689) in the Source scale. The average SEBs score of the experimental group (M = 3.10, SD = .830) was significantly better than that of the control group (M = 2.77, SD = .572) in the Certainty scale. However, there was no difference in the "Development" (t = -0.603, p = .548, effect size d = .088) or "Justification" (t = -.829, p = .414, effect size d = -.135) scales.

Table 5
Independent Sample t Test Results of the Items of the Two Groups' Post-test SEBs

Item	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Source	Control	81	2.95	.861	-5.923	149	< .05	-.975
	Experimental	70	3.71	.689				
Certainty	Control	81	2.77	.830	-2.914	142.214	< .05	-.463
	Experimental	70	3.10	.572				

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Item	Group	*N*	*M*	*SD*	*t*	*df*	*p*	*d*
Development	Control	81	4.10	.496	.603	149	.548	.088
	Experimental	70	4.05	.629				
Justification	Control	81	4.18	.478	-.829	149	.414	-.135
	Experimental	70	4.25	.555				

Discussion

The Practice of POE Improved Fifth Graders' Learning Achievement

Through participating in explorations and discussion activities, the experimental group students regulated their thinking about their prior knowledge and reflected on it, in order to form their own connections among the science concepts (Jerrim et al., 2020; Zhang, 2019). Accordingly, one of the aims of the study was to explore the different influences of the POE learning inquiry model and traditional teaching on fifth graders' concept achievement in the Light Refraction unit. According to the independent sample *t* test results, students in the two groups had similar prior knowledge in Light Refraction, but there were significant differences in their knowledge after the intervention, indicating that there were significant differences in the influence of the two methods of teaching on fifth graders' concept achievement of Light Refraction. The result was supported by some previous studies, for example, POE inquiry learning promoted students' learning of scientific concepts (Bunprom et al., 2019; Fitriani et al., 2020; Karamustafaoğlu & Mamlok-Naaman, 2015), indicating that the POE inquiry-based learning method was more effective than traditional teaching in terms of learners' learning of the concepts of Light Refraction.

The POE Inquiry-Based Learning Model Improved Fifth Graders' SEBs

The students' SEBs are generated between knowledge claims and draw on experiences of the knowledge building process (Kienhues et al., 2016), where POE regulating the process of knowing is particularly relevant for knowledge comprehension (Braten et al., 2015). Based on the independent sample *t* test results, both the experimental and control group learners' prior SEBs were similar, but there was a significant difference in their SEBs after the intervention, indicating that the experimental group could lead to better SEBs than the control group. The findings supported the earlier studies which also found positive effects of POE on students' SEBs (Chen, 2017; Cheng, 2018), indicating a significant difference in the "Source" and "Certainty" dimensions for the control group and experimental group. However, there was no difference in the "Development" or "Justification" dimensions. The results were parallel to the findings of Conley et al.'s (2004), which suggested that students develop SEBs that more sophisticated "source" and "certainty" were constructed and without significantly changing beliefs about "development" and "justifications." Therefore, the approach of POE inquiry learning facilitated the fifth graders' "Source" and "Certainty" dimensions in two 40-minute lessons.

The POE applied to Light Refraction learning was designed to encourage prediction, observation, and explanation, but it ignored argumentation. In addition, the time of the observation phase took half of each lesson. It was obvious that emphasizing observation limited the opportunities of the learners to use evidence to debate their ideas and to reflect on their inquiry activities. This might account for the lack of significant change in the dimensions of development and justification. The underlying mechanism of this change should be more validated in studies that make comparisons with science classrooms that adopt inquiry-based teaching strategies with a focus on argumentation and reflection (Herrenkohl et al., 1999).

Conclusions and Implications

This study presented the three round POE inquiry-based learning in the Light Refraction unit and explored its effects on fifth graders' concept achievements and their SEBs. It could be concluded that learners achieved

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better concept achievements and SEBs in POE inquiry-based learning. In addition, it showed better positive effects of POE inquiry-based learning on learners' SEBs in the subscales of "source" and "certainty". Therefore, when using the POE inquiry-based model teaching, instructors were suggested to strengthen the cultivation of learners' SEBs in the scales of "development" and "justifications."

The implementation of the POE inquiry-based learning model is expected to provide theoretically and practically help for learners to learn simple science concepts. Theoretically, this implementation can help learners to improve their concept achievement, and to build views of their own knowledge and knowing in science. Practically, the overall results of the present research suggest that when learners practice POE, it can help them understand Light Refraction and achieve better learning performance. Therefore, the POE model can be applied to promote students' science learning and help learners gain a better understanding of exactly the generation and development of scientific knowledge. This study has some enlightenment for instructors that it needs to design different inquiry models according to different scientific concepts so as to effectively improve learner's concept achievement. It is of great significance to the education system of science instructors and enhancing their competencies for inquiry-based teaching.

The implementation of the POE inquiry-based learning model is expected to provide the help for improving learners' SEBs. Learners' SEBs can be strengthened based on applying the POE learning-based model to teaching. Therefore, it is suggested that instructors use the POE learning-based model in science courses to improve learners' SEBs. It is very important that the instructor applies inquiry teaching strategies to make learners play an active role in the teaching process. This study has an important contribution for instructors to design the teaching process using POE inquiry-based model teaching strategies. In scientific learning inquiry, there is often more than one prediction or question. If all of the predictions and questions are put at the beginning phase, it may be difficult to focus on the one prediction. However, if one POE model is explored one prediction in one round, many details can be focused on. Therefore, if there are a lot of predictions, it is suggested that instructors construct learners' SEBs one prediction at a time, and one POE model at a time.

Limitations

This study has some limitations. The study implemented one unit of teaching. Therefore, the suitability of the POE inquiry model for other new units or new subjects is not certain. Thus, future studies can select more units or topics of science to conduct POE for students to learn and examine their SEBs and learning achievement. Teachers have been found to hold sophisticated scientific epistemological beliefs. Education can be enhanced if teachers are asked to examine their belief structures. This might in turn impact their SEBs beliefs about teachers' and students' roles. Therefore, in the future, it is suggested that the focus be on research of teachers' epistemological beliefs, especially in science education, and on what types of experiences impact the development of these beliefs and conceptions. In addition, due to the period of this study being short, with just 80 minutes over a period of two classes, the results of this study suggested that learners developed SEBs that the more sophisticated "source" and "certainty" were constructed and without significantly changing beliefs about "development" and "justifications." Therefore, future studies may implement longer experiments to explore if the POE inquiry learning teaching can facilitate the students' "Source" and "Certainty" dimensions.

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Declaration of Interest

Authors declare no competing interest.

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References

Annisa, D., & Rohaeti, E. (2018). The effect of inquiry-based learning on students' understanding of the chemical equilibrium concept. In *AIP Conference Proceedings*, *2021*(1), Article 108. https://doi.org/10.1063/1.5062823

Areepattamannil, S., Cairns, D., & Dickson, M. (2020). Teacher-directed versus inquiry-based science instruction: Investigating links to adolescent students' science dispositions across 66 countries. *Journal of Science Teacher Education*, *31*(6), 675-704. https://doi.org/10.1080/1046560X.2020.1753309

Arsy, H. I., Prasetyo, A. P. B., & Subali, B. (2019). Predict-observe-explain strategy with group investigation effect on students' critical thinking skills and learning achievement. *Journal of Primary Education*, *8*(4), 75-83. https://journal.unnes.ac.id/sju/index.php/jpe/article/view/29109

Ayvacı, H. Ş. (2013). Investigating the effectiveness of predict-observe-explain strategy on teaching photo electricity topic. *Journal of Baltic Science Education*, *12*(5), 548-564. https://doi.org/10.3402/meo.v18i0.23249

Banawi, A., Sopandi, W., Kadarohman, A., & Solehuddin, M. (2019). Prospective primary school teachers' conception change on states of matter and their changes through predict-observe-explain strategy. *International Journal of Instruction*, *12*(3), 359-374. https://doi.org/10.29333/iji.2019.12322a

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1992). Theory into practice: How do we link. *Constructivism and the Technology of Instruction: A Conversation*, *8*(1), 17-34.

Braten, I., Stromso, H. I., & Ferguson, L. E. (2015). The role of epistemic beliefs in the comprehension of single and multiple texts. In *Handbook of individual differences in reading* (pp. 67-79). Routledge.

Bumbacher, E., Salehi, S., Wieman, C., & Blikstein, P. (2018). Tools for science inquiry learning: Tool affordances, experimentation strategies, and conceptual understanding. *Journal of Science Education and Technology*, *27*(3), 215-235. https://doi.org/10.1007/s10956-017-9719-8

Bunprom, S., Tupsai, J., & Yuenyong, C. (2019). Learning activities to promote the concept of engineering design process for grade 10 students' ideas about force and motion through Predict-Observe-Explain (POE). *Journal of Physics: Conference Series*, *1340*(1), Article 81. https://iopscience.iop.org/issue/1742-6596/1340/1

Cairns, D., & Areepattamannil, S. (2019). Exploring the relations of inquiry-based teaching to science achievement and dispositions in 54 countries. *Research in Science Education*, *49*(1), 1-23. https://doi.org/10.1007/s11165-017-9639-x

Chen, B. (2017). Fostering scientific understanding and epistemic beliefs through judgments of promisingness. *Educational Technology Research and Development*, *65*(2), 255-277. https://doi.org/10.1007/s11423-016-9467-0

Chen, J. C. (2020). Developing a cycle-mode POED model and using scientific inquiry for a practice activity to improve students' learning motivation, learning performance, and hands-on ability. *Interactive Learning Environments*, *28*(1), 1-13. https://doi.org/10.1080/10494820.2020.1716023

Cheng, K. H. (2018). Surveying students' conceptions of learning science by augmented reality and their scientific epistemic beliefs. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1147-1159. https://doi.org/10.29333/ejmste/81811

Çalık, M., & Bayçelebi, Z. (2020). Developing and implementing prediction-observation-explanation worksheets of healthy foods. *Elementary Education Online*, *19*(3), 18-39. https://doi.org/10.17051/ilkonline.2020.735188

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational psychology*, *29*(2), 186-204. https://doi.org/10.1016/j.cedpsych.2004.01.004

Coştu, B., Ayas, A., & Niaz, M. (2012). Investigating the effectiveness of a POE-based teaching activity on students' understanding of condensation. *Instructional Science*, *40*(1), 47-67. https://doi.org/10.1007/s11251-011-9169-2

Firman, M. A., Ertikanto, C., & Abdurrahman, A. (2019). Description of meta-analysis of inquiry-based learning of science in improving students' inquiry skills. *In Journal of Physics: Conference Series*, *1157*(2), 1-7. https://iopscience.iop.org/article/10.1088/1742-6596/1157/2/022018/meta

Fitriani, A., Zubaidah, S., Susilo, H., & Al Muhdhar, M. H. I. (2020). The effects of integrated problem-based learning, predict, observe, explain on problem-solving skills and self-efficacy. *Eurasian Journal of Educational Research*, *85*, 45-64. https://doi.org/10.14689/ejer.2020.85.3

Gillies, R. M., & Rafter, M. (2020). Using visual, embodied, and language representations to teach the 5E instructional model of inquiry science. *Teaching and Teacher Education*, *87*, Article 17. https://doi.org/10.1016/j.tate.2019.102951

Gunstone, R. F. (1990). Children's science: A decade of developments in constructivist views of science teaching and learning. *The Australian Science Teachers Journal*, *36*(4), 9-19. https://www.researchgate.net/publication/289539969

Herrenkohl, L. R., Palincsar, A. S., DeWater, L. S., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A socio-cognitive approach. *Journal of the Learning Sciences*, *8*(3-4), 451-493. https://doi.org/10.1080/10508406.1999.9672076

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, *25*(4), 378-405. https://doi.org/10.1006/ceps.1999.1026

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, *67*(1), 88-140. https://doi.org/10.3102/00346543067001088

Hong, J. C., Hwang, M. Y., Liu, M. C., Ho, H. Y., & Chen, Y. L. (2014). Using a "prediction-observation-explanation" inquiry model to enhance student interest and intention to continue science learning predicted by their internet cognitive failure. *Computers & Education*, *72*, 110-120. https://doi.org/10.1016/j.compedu.2013.10.004

Hong, J. C., Tsai, C. R., Hsiao, H. S., Chen, P. H., Gu, J. J., & Sitthiworachart, J. (2019). The effect of the "Prediction-observation-quiz-explanation" inquiry-based e-learning model on flow experience in green energy learning. *Computers & Education*, *133*, 127-138. https://doi.org/10.1016/j.compedu.2013.10.004

https://doi.org/10.33225/jbse/21.20.664

Hsu, C. Y., Tsai, M. J., Hou, H. T., & Tsai, C. C. (2014). Epistemic beliefs, online search strategies, and behavioral patterns while exploring socioscientific issues. *Journal of Science Education and Technology*, *23*(3), 471-480. https://doi.org/10.1007/s10956-013-9477-1

Jasdilla, L., Fitria, Y., & Sopandi, W. (2018). Predict Observe Explain (POE) strategy toward mental model of primary students. *In Journal of Physics: Conference Series*, *1157*(2), Article 42. https://doi.org/10.1088/1742-6596/1157/2/022043

Jerrim, J., Oliver, M., & Sims, S. (2020). The relationship between inquiry-based teaching and students' achievement: New evidence from a longitudinal PISA study in England. *Learning and Instruction*, *61*(1), 35-44. https://doi.org/10.1016/j.learninstruc.2018.12.004

Kampa, N., Neumann, I., Heitmann, P., & Kremer, K. (2016). Epistemological beliefs in science—a person-centered approach to investigate high school students' profiles. *Contemporary Educational Psychology*, *46,* 81-93. https://doi.org/10.1016/j.cedpsych.2016.04.007

Karamustafaoğlu, S., & Mamlok-Naaman, R. (2015). Understanding electrochemistry concepts using the predict-observe-explain strategy. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(5), 923-936. https://doi.org/10.12973/eurasia.2015.1364a

Ketpichainarong, W., Panijpan, B., & Ruenwongsa, P. (2010). Enhanced learning of biotechnology students by an inquiry-based cellulase laboratory. *International Journal of Environmental and Science Education*, *5*(2), 169-187.

Kienhues, D., Ferguson, L. E., & Stahl, E. (2016). Diverging information and epistemic change. In J. A. Greene, W. A. Sandoval, & I. Braten (Eds.), *Handbook of epistemic cognition* (pp. 318-330). Routledge.

Latifah, S., Irwandani, I., Saregar, A., Diani, R., Fiani, O., Widayanti, W., Deta, U.A. (2019). How the Predict-Observe-Explain (POE) learning strategy remediates students' misconception on Temperature and Heat materials. *In Journal of Physics: Conference Series*, *1171*(1), 1-6. https://doi.org/10.1088/1742-6596/1171/1/012051

Liang, J. C., & Tsai, C. C. (2010). Relational analysis of college science-major students' epistemological beliefs toward science and conceptions of learning science. *International Journal of Science Education*, *32*(17), 2273-2289. https://doi.org/10.1080/09500690903397796

Lin, T. J., Deng, F., Chai, C. S., & Tsai, C. C. (2013). High school students' scientific epistemological beliefs, motivation in learning science, and their relationships: A comparative study within the Chinese culture. *International Journal of Educational Development*, *33*(1), 37-47. https://doi.org/10.1080/09500693.2017.1384593

Mamun, A. A., Lawrie, G.A., & Wright, T. (2020). Instructional design of scaffolded online learning modules for self-directed and inquiry-based learning environments. *Computers & Education*, *144*, Article 5. https://doi.org/10.1016/j.compedu.2019.103695

Mason, L., & Bromme, R. (2010). Situating and relating epistemological beliefs into metacognition: Studies on beliefs about knowledge and knowing. *Metacognition and Learning*, *5*(1), 1-6. https://doi.org/10.1007/s11409-009-9050-8

Mayer, R. (2014). Cognitive theory of multimedia learning. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning (Cambridge handbooks in psychology)* (pp. 31-48). Cambridge University Press.

Özdem, Y., Çavas, P., Çavas, B., Çakıroglu, J., & Ertepınar, H. (2010). An investigation of elementary students' scientific literacy levels. *Journal of Baltic Science Education*, *9*(1), 6-19. http://oaji.net/articles/2014/987-1404740965.pdf

Özgür, S. D., Yılmaz, A. (2017). The effect of inquiry-based learning on gifted and talented students' understanding of acids-bases concepts and motivation. *Journal of Baltic Science Education*, *16*(6), 994-1008. http://oaji.net/articles/2017/987-1513971383.pdf

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., Manoli C. C., Zacharia. Z. C., & Tsourlidaki, E. (2015) Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Peffer, M. E., & Ramezani, N. (2019). Assessing epistemological beliefs of experts and novices via practices in authentic science inquiry. *International Journal of STEM Education*, *6*(1), 1-3. https://doi.org/10.1186/s40594-018-0157-9

Pegg, J. M. (2006). *Developing explanations: Student reasoning about science concepts during claims-evidence inquiry lessons*. PH.D. diss. Corvallis, OR: Department of science and Math Education. Oregon State University.

Rakkapao, S., Pengpan, T., Srikeaw, S., & Prasitpong, S. (2014). Evaluation of POE and instructor-led problem-solving approaches integrated into force and motion lecture classes using a model analysis technique. *European Journal of Physics*, *35*(1), Article 16. https://doi.org/10.1088/0143-0807/35/1/015016

She, H. C., Lin, H. S., & Huang, L. Y. (2019). Reflections on and implications of the Programme for International Student Assessment 2015 (PISA 2015) performance of students in Taiwan: The role of epistemic beliefs about science in scientific literacy. *Journal of Research in Science Teaching*, *56*(10), 1309-1340. https://doi.org/10.1002/tea.21553

Sarwi, S., Hidayah, N., & Yulianto, A. (2019). Guided inquiry learning model to improve the conceptual understanding and scientific work skills of high school students in Central Java. In *Journal of Physics: Conference Series*, *1170*(1), Article 83. https://doi.org/10.1088/1742-6596/1170/1/012083

Songer, N. B., & Linn, M. C. (1991). How do students' views of science influence knowledge integration? *Journal of Research in Science Teaching*, *28*(9), 761-784. https://doi.org/10.1002/tea.3660280905

Suarez, A., Specht, M., Prinsen, F., Kalz, M., & Ternier, S. (2018). A review of the types of mobile activities in mobile inquiry-based learning. *Computers & Education*, *118*, 38-55. https://doi.org/10.1016/j.compedu.2017.11.004

Tsai, C. C., Ho, H. N. J., Liang, J. C., & Lin, H. M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*, *21*(6), 757-769. https://doi.org/10.1016/j.learninstruc.2011.05.002

Yang, I. Ho., Na, J. C., Lim, S. M., Lim, J. K., & Choi, H. D. (2008). An analysis of elementary schools' science test items by Klopfer's taxonomy of educational objectives: Focusing on the first term of the 5th grade. *Journal of Korean Elementary Science Education*, *27*(3), 221-232.

https://doi.org/10.33225/jbse/21.20.664

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Yang, X., Zhao, G., Zhao, Q., & Yan, X. (2019). The relationship between students' scientific epistemological beliefs and their performance of knowledge integration in Web-based Inquiry. In 2019 Eighth International Conference on Educational Innovation through Technology (EITT) (pp. 19-24). IEEE. https://doi.org/10.1109/EITT.2019.00013

Zhang, L. (2019). "Hands-on" plus "inquiry"? Effects of withholding answers coupled with physical manipulations on students' learning of energy-related science concepts. *Learning and Instruction*, *60*, 199-205. https://doi.org/10.1016/j.learninstruc.2018.01.001

Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (STEM) across genders and grade levels. *Journal of Baltic Science Education*, *18*(3), 466-480. https://doi.org/10.33225/jbse/19.18.466

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