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THE IMPACT OF THE PREDICTION-OBSERVATION-EXPLANATION MODEL ON PRESCHOOLERS' UNDERSTANDING OF GEAR CONCEPTS THROUGH BLOCK PLAY

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Abstract. *The complexity of gear concepts, often misunderstood by young children, highlights the need for educational frameworks beyond simple play. To examine the effects of using the prediction, observation, and explanation (POE) model in building block activities, a true experimental design was implemented. A total of 49 preschoolers were randomly assigned to either an experimental group, which engaged with building blocks embedded with the POE model, or a control group, which followed a building instruction guide. Data were gathered through pretests, posttests, and two-week delayed tests administered to all participants. The theoretical framework for this study was based on the POE model, emphasizing the importance of prediction, observation, and explanation in the learning process. The results revealed that the POE model had positive impacts on fostering young children's acquisition of gear concepts. Specifically, gear speed and gear direction were identified as the most challenging concepts for preschoolers to grasp. The results highlight the critical role of children's reflection in learning these concepts. The participants' common naive conceptions about gear function, gear speed, and gear direction were identified. The implications of these results highlight the importance of incorporating reflective practices in early childhood education to enhance concept acquisition and address misconceptions.*
Keywords: *science education, gear concepts, building blocks, alternative conceptions, early childhood education*

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Introduction

Nurturing young children's ability to think scientifically and grasp fundamental scientific concepts is essential in early childhood education. Young children, much like natural scientists, exhibit an inherent curiosity about their surroundings and engage in learning through exploration, observation, and inquiry (Kefi & Yildiz, 2024). If cultivated properly, this innate inquisitiveness to science learning not only fosters positive attitudes toward the subject but also enhances the understanding of concepts that will be encountered later in formal education (Fragkiadaki et al., 2023; Eshach & Fried, 2005).

Contemporary educational approaches in science education are largely influenced by constructivism. Within this framework, understanding an object involves more than mere observation or replication; it requires actively modifying and transforming the object. Specifically, one must either assimilate new information or experiences into existing cognitive structures or accommodate these structures to integrate new information or experiences, in order to achieve cognitive balance between assimilation and accommodation (Piaget, 1964). Consequently, learning is conceptualized as an active process where individuals, serving as central agents in the creation and acquisition of knowledge, construct their understanding through dynamic interactions with both physical and social environments (Piaget, 1964; Driver et al., 1994). In the context of early science education, this theory emphasizes the importance of providing opportunities for young children to engage in scientific inquiry (Peterson & French, 2008; Seimears et al., 2012). When children explore their surroundings and ask questions, they can actively construct their personal understanding of relevant scientific phenomena. Meanwhile, teachers can act as facilitators to foster the mental connections among students' actual experience, personal understanding, and scientific concepts by triggering and reconciling their cognitive dissonances (Taylor et al., 1997; Valanides,

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2002). Baviskar et al. (2009) identified four essential features of constructivist instruction: eliciting prior knowledge, creating cognitive dissonance, applying new knowledge with feedback, and reflecting on learning. These features serve as critical components in designing effective science instruction that aligns with constructivist principles, ensuring that learning is both meaningful and sustainable for young learners.

An effective approach, fulfilling the four features of constructivism and commonly used in science education is the Prediction-Observation-Explanation (POE) strategy. This approach encourages children to actively engage with scientific concepts, make predictions, observe outcomes, and refine their understanding based on these observations (White & Gunstone, 1992). The ultimate goal of the POE model is to probe the nature of the beliefs which students use to interpret real events. It has been conducted by performing three tasks; first of all, students individually need to indicate both their prediction and the reasons supporting the prediction. This process may help to elicit learners' prior knowledge. Second, they observe what they see and record the observation, which induces cognitive dissonance to challenge that knowledge. Last, they explain possible discrepancies or congruences between what they predicted and what they observed. This provides opportunities to apply new knowledge with feedback and culminates in reflection to solidify learning. This sequence is meaningfully associated with each other and should not be modified or missed (White & Gunstone, 1992). The POE model has been widely applied in diverse educational domains and significantly improved students' mathematical performance (Yang & Chen, 2021), promoted fifth graders' science concept achievement and scientific epistemological beliefs (Zhao et al., 2021), as well as improved fifth graders' conceptual understanding of the States of Matter, Heat, and Temperature (Karsli Baydere, 2021).

White and Gunstone (1992) have suggested that the POE model can be used with much younger students. For instance, Hsu et al. (2011) have integrated the POE model into game-based learning to facilitate preschoolers' acquisition of scientific concepts regarding light and shadow. They have found that those who played the game with POE embedded outperformed their counterparts. Similarly, integrating POE into learning activities to promote preschoolers' understanding regarding the properties of air, Liang (2011) has found that the activities could not only enhance scientific learning, attract attention, and arouse curiosity, but also offer teachers an ideal approach to probe children's understanding. Zudaire et al. (2021) have implemented inquiry-based science projects combined with the POE model and found that young children could progressively offer better descriptions and justifications, as well as show more learning interest. Vilhunen et al. (2023) have indicated that through engaging in predicting, observing, and explaining, learners become more involved in connecting models as tools to explain observations and find answers to questions, thereby fostering critical thinking skills and enabling the effective application of knowledge in varied contexts.

Gears, which are commonly part of children's everyday experiences, can be effectively incorporated into science activities to deepen their understanding of related scientific concepts and serve as ideal instructional materials and toys for young children to learn and play with (Chalmers et al., 2017; Stoycheva & Perkins, 2016; Reuter & Leuchter, 2021, 2022). The application of gears is commonly seen in bicycles, wind-up toys, and clocks. Children can not only easily manipulate, test, and modify gears, but they can also gain straightforward feedback by observing their arrangement and how they transmit motion. This provides a thorough investigation of how these simple machines work and enhances their comprehension of cause-and-effect relationships, which later fosters their understanding of more complex systems and the underlying mechanisms. In addition, connecting these physics concepts to real-world applications, children can better appreciate the relevance and importance of what they are learning. However, researchers (Reuter & Leuchter, 2021) have indicated that young children often hold alternative conceptions about gears. They have examined the conceptions of gears among children aged 5 to 10 years as well as adults, identifying that the accuracy of the concepts increases with age. The younger children's alternative conceptions include beliefs that contiguous gears turn in the same direction, and that the larger the gear, the faster it turns. They have further conducted a 45-minute intervention study to compare whether guided play or free play could improve 5- to 6-year-olds' comprehension of gears' turning direction and speed. However, no statistically significant difference has been found in the learning gains. This has implied that merely guided play or free play might not necessarily promote effective learning in children's block play. It is pedagogy that matters.

Similarly, Asghar et al. (2019) have identified that many students had alternative conceptions of the turning speed of a gear set. Reuter and Leuchter (2022) have designed an engineering gear task to probe how young children's individual characteristics relate to problem-solving performance. They found that the higher goal awareness, as well as testing and optimizing, the better the solution quality. Children with better spatial skills tend to have better solutions. Chambers et al. (2008) have examined the impacts of robotic education on fourth graders' conceptions of gears and mechanical advantage. The results have shown that students encounter difficulty in clearly explaining

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the gear function and the relations of gears to a vehicle's power and speed since children's alternative conceptions are resilient to change, the necessity of combining instructional approaches into early stages of teaching gears becomes critical (Asghar et al., 2019; Chambers et al., 2008). This highlights the value of structured frameworks (e.g., the Predict-Observe-Explain (POE) model, which enhances learning by engaging children in prediction, observation, and explanation, thus deepening their understanding and concept retention.

Research Aim and Research Questions

In sum, previous studies mainly have focused on examining young children's conceptions of gears, with few examining how building block activities embedded with educational approaches influence preschoolers' learning performance. Thus, this study aimed to fill this gap by probing whether integrating the POE model into building block activities can improve preschoolers' acquisition of gear concepts. Two research questions included:

1. What is the impact of integrating the POE model into building block activities on improving the preschoolers' acquisition of gear concepts?
2. What are alternative conceptions of gears the preschoolers still possessed after the treatments?

Research Methodology

To address the research questions, a true experimental design was selected. 49 preschoolers were randomly assigned to either an experimental group or a control group. The scope of this research encompassed the impact of the Predict-Observe-Explain (POE) model on preschoolers' engagement with building block activities. The theoretical framework for this study was based on the POE model, which emphasized the importance of prediction, observation, and explanation in learning processes. This approach aimed to enhance cognitive development through structured play. The experimental group engaged in building block activities embedded with the POE model, while the control group participated in similar activities without the POE model. Participants individually took a pretest several days before the treatment began. Each child independently completed four building block activities, each lasting approximately 40 minutes, over four consecutive days in one week. Posttests were conducted immediately after the completion of all activities, and a delayed test was administered two weeks later to assess the retention of learned concepts. All pretests, posttests, and the 2-week delayed tests were video recorded for further analysis.

Participants

The initial 60 participants were randomly selected from a larger pool of eligible preschoolers aged 4-6 years, with no prior formal education related to gear or pulley concepts. Parents were informed about the study, and consent was obtained for all participants. However, due to some participants not completing the study, the final sample consisted of 49 preschoolers. Among the final participants, 22 children (11 boys and 11 girls) were assigned to the experimental group, and 27 children (15 boys and 12 girls) were assigned to the control group. Each child participated individually, and their interactions with the research assistant were video recorded for further analysis. None of them had ever received any education related to gear or pulley concepts. Participation was voluntary, with participants informed that they could withdraw at any time without repercussions and could omit any questions they preferred not to answer. Pseudonyms were assigned to ensure confidentiality and non-identifiability. Only children with signed parental consent forms were allowed to participate in the study.

Treatment

The courses consisted of four topics: car, blender, fishing pole, and spinning cups (see Figure 1). Each topic lasted approximately 40 minutes and occurred consecutively over a week. The total treatment time was 160 minutes. The topics were designed to instruct on gear concepts, specifically gear function (e.g., how two or more gears mesh together to create motion), gear speed (e.g., how the sizes of gears influence the speed of spinning gears), and gear direction (e.g., when two gears mesh together, the second one always rotates in the opposite direction), using the LEGO Early Simple Machines Set (9656). Table 1 shows how each topic relates to the targeted concepts. Both the experimental group and the control group received the same learning content, except for the experimental group being prompted pedagogically following the POE approach. For instance, while constructing a blender, the research assistant prompted the child with the question, *Which gear (blue or yellow) will run faster*

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if I rotate the yellow handle? The child should make a prediction and provide a rationale before proceeding with any movement. The assistant recorded the description and then allowed the child to manipulate the blocks and observe the consequences. Two tags were pasted on each gear to help the child identify differences in the speed and direction of two gears. In the meantime, the assistant asked the child to explain the discrepancies or congruences between his/her prediction and observation. On average, the sequence of prediction, observation, and explanation repeatedly occurred at least six times in each one of the four topics. However, children in the control group merely constructed the objects according to the guidance of the assistant. Except for questions regarding construction, no question was prompted to reflect the targeted concepts.

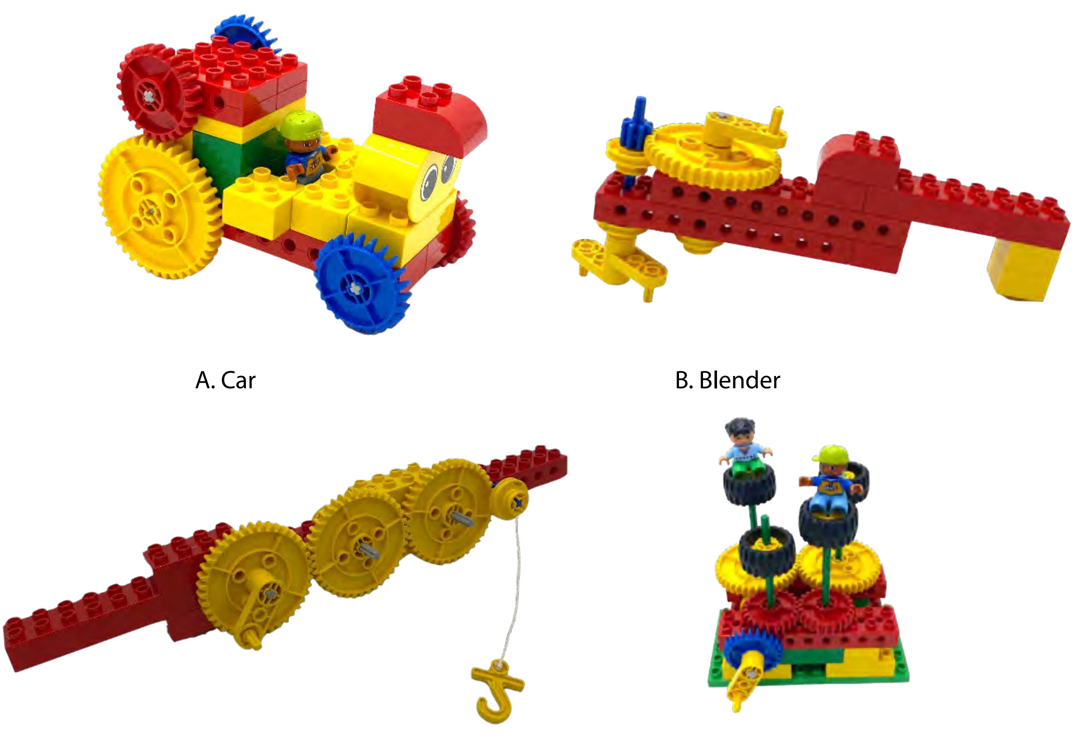
The control group received instruction through a teacher-directed teaching approach. In this group, the teaching process involved the gradual presentation of elements and the sequential activation of gear devices. Specifically, the children in the control group followed a step-by-step guide to construct the gear mechanisms, with the research assistant demonstrating each step without encouraging predictions or reflective discussions. The gear devices were simply switched on to show their function. This method contrasts with the constructive teaching procedure used in the experimental group, where the POE model was employed to engage children in making predictions, observations, and explanations.

Table 1
Overview of Learning Activities Related to Gear Concepts

Topics	Gear function	Gear speed	Gear direction
Car	V	V	
Blender	V	V	
Fishing pole	V		V
Spinning cup	V	V	V

Note: The symbol "V" denotes a learning activity associated with gear concepts.

Figure 1
The Four Learning Activities of The Treatment



A. Car B. Blender

C. Fishing pole D. Spinning cup

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Measurement

Based on Treagust's (1988) two-tier diagnostic design, an instrument of 19 items to measure the participants' gear concepts was developed; respectively, six items for gear function, seven for gear speed, and six for gear direction. For instance, the assistant displayed an image (see Figure 2) and examined children's descriptive knowledge about the targeted concept in the first tier. That is, can one of the three gears be spun? During the second tier, the assistant probed the children's justification for their choice made in the first tier, that is, *what was your rationale*? A participant scored 1 point if both the answer (first tier) and the reason (second tier) were accurate and sound. Thus, the total score was 19. All the items were verified by experts of science education and preschool teachers. Only one researcher conducted the analysis to ensure the reliability in scoring. The pretest, posttest, and 2-week delayed test used the same instrument. The children took the tests individually; the research assistant read the questions and recorded the students' responses.

Figure 27
The Sample Item of Assessment

Data Analysis

To address the first research question, the assumption of homogeneity of regression slopes and normality (using the Shapiro-Wilk test) were first examined. A one-way analysis of covariance (ANCOVA) was attempted to assess the differences in post-test and delayed test outcomes between the two groups, using their pretest scores as a control variable. However, since the assumption of homogeneity of regression slopes was not met, the Johnson-Neyman procedure was conducted as an alternative to ANCOVA (D'Alonzo, 2004). The second research question was addressed by analyzing the preschoolers' individual interviews in the posttest and 2-week delayed test to further explore their alternative conceptions of gears after the treatments.

Research Results

Effect of POE Model on Preschoolers' Gear Concept Acquisition

Table 2 shows the descriptive statistics for the learning performance of the two groups. As shown, the average scores of gear speed and gear direction are lower than that of gear function among the three tests, suggesting that these two concepts are more complicated. In addition, the full score for each test is 19, but the preschoolers' average scores are below 13 for the experimental group and 7 for the control group. This implies that there is still room for improvement. Further analyses were conducted to examine the differences between groups.

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Table 2
Descriptive Results of Both Groups' Learning Performance

Type	Concepts	Experimental group		Control group	
		M	*SD*	*M*	*SD*
Pretest	Gear function	3.14	1.7	3.11	1.76
	Gear speed	0.91	1.51	0.74	0.9
	Gear direction	0.68	1.21	0.7	1.2
	Total	4.73	3.03	4.56	2.83
Posttest	Gear function	4.86	1.04	3.67	1.78
	Gear speed	4.14	2.29	1	1.24
	Gear direction	2.95	2.13	1.74	1.95
	Total	11.95	3.97	6.41	3.72
Delayed test	Gear function	4.82	1.14	3.63	1.74
	Gear speed	4.14	2.38	1.11	1.45
	Gear direction	3.32	2.01	1.59	2
	Total	12.27	4.22	6.33	4.04

Originally, the study aimed to conduct an analysis of covariance (ANCOVA) to examine the effects of the POE model on the posttest of both groups. The results of the Shapiro-Wilk test indicated that the pretest ($W = 0.97$, $p > .05$), posttest ($W = 0.9$, $p > .05$), and delayed test ($W = 0.96$, $p > .05$) were normally distributed; however, the assumption of homogeneity of regression slopes of the experimental and control groups was violated ($F = 15.94$, $p < .001$), suggesting that the magnitude of the treatment effect was not the same for different levels of the experimental and control groups (D'Alonzo, 2004). Thus, the results of the Johnson-Neyman technique are displayed in Figures 3 and 4. Figure 3 shows the regression lines of the posttest scores against the pretest scores of the experimental group and the control group. As shown, the critical point (8.70) indicated that when children's pretest scores were higher than 8.70, there was no statistically significant difference in the treatment effect between the experimental and the control groups. For children whose pretest score was lower than 8.70, which made up 91.84% (45 of the 49 participants), the experimental group significantly outperformed the control group. This suggested that the POE model could effectively foster the children's learning gains; however, this effect was not significant for students belonging to the top 8%.

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Figure 3

The Regression Lines of The Posttest Scores against the Pretest Scores of the Two Groups

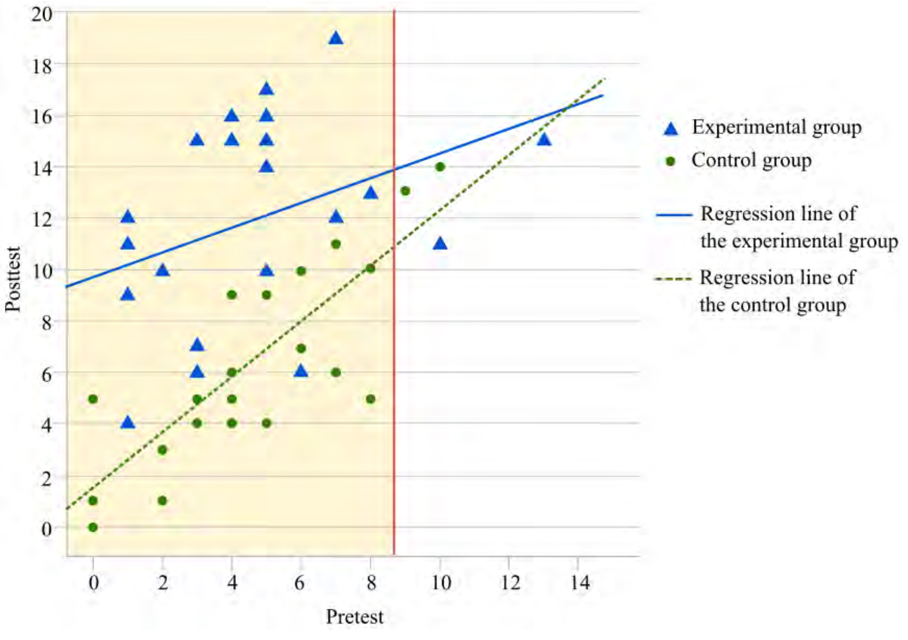

Figure 4 shows the regression lines of the delayed test scores against the pretest scores of the experimental group and the control group. As shown, the critical point (9.41) indicated that when children's pretest scores were higher than 9.41, there was no statistically significant difference in the treatment effect between the experimental and the control groups. For children whose pretest score was lower than 9.41, which makes up 93.88% (46 of the 49 participants), the experimental group significantly outperformed the control group. This suggested that the positive learning gains of playing with building blocks with the POE model combined can be retained after 2 weeks of treatment; however, this effect was not significant for the students belonging to the top 6%.

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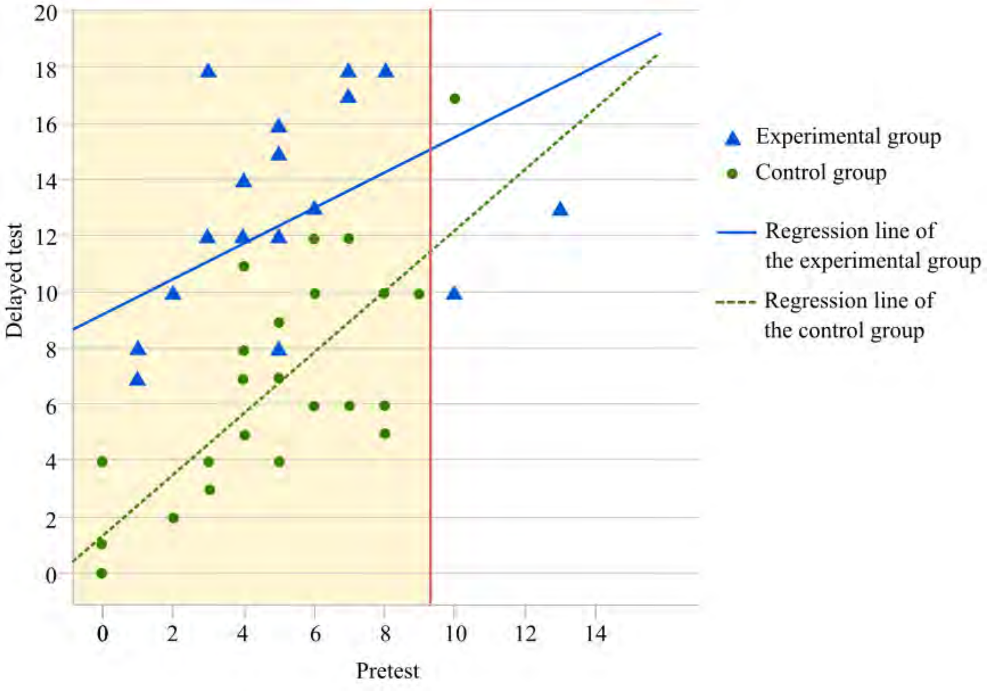
Figure 4

The Regression Lines of the Delayed Test Scores against the Pretest Scores of the Two Groups



Preschoolers' Alternative Conceptions of Gears Post-Treatment

The participants' alternative conceptions of gears in both the experimental group and the control group were collected from their responses to the pretest, posttest, and 2-week-delayed test items. Through content analysis, the data were categorized into gear function, gear speed, and gear direction. Gear function refers to how two or more gears mesh together to create motion. Table 3 displays the categories and frequency of students' alternative conceptions of gear function. As shown, despite the treatments, preschoolers of both groups constantly misunderstood that three meshing gears in a triangle shape (1 top 2 bottom, see Figure 2) can rotate. Although the participants experienced interlocking two, three, and four gears during the intervention, some children might think that gears can still rotate whenever they are interlocked with other gears (see Example 1).

Example 1:

Researcher: *Look at these three gears interlocking in a triangle shape. Can they spin?*

Child: *Yes.*

Researcher: *Why do you think so?*

Child: *Their teeth are meshing together, so they can spin.*

Table 3

Number of Students with Alternative Conceptions about Gear Function

Gear function	Experimental group			Control group		
	Pretest	Posttest	Delayed test	Pretest	Posttest	Delayed test
Meshing gears of different sizes cannot rotate.	6	1	4	2	1	2
Unmeshed gears can rotate.	3	0	0	5	0	0

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Gear function	Experimental group			Control group		
	Pretest	Posttest	Delayed test	Pretest	Posttest	Delayed test
Only gears with a handle can rotate.	0	1	1	0	0	7
Three meshing gears in a triangle shape (1 top 2 bottom) can rotate.	25	14	8	27	20	23
Four meshing gears in a rectangle shape (2 top 2 bottom) cannot rotate.	3	0	2	4	2	3
I do not know.	20	4	0	8	6	11
Total	57	20	15	46	29	46

Some children mistakenly attributed the reason why meshing gears can rotate to the attachment of the crank. That is, meshing gears cannot rotate without a crank connected (see Example 2). In addition, they viewed meshing gears of different sizes as non-rotatable despite an even number of gears being connected together (see Example 3).

Example 2:

Researcher: *Here we have three gears connected. Can we turn them?*
Child: *No.*
Researcher: *Why do you think so?*
Child: *Because there is no crank on them.*

Example 3:

Researcher: *Now we have two small red gears and two big yellow gears meshed together in a rectangle shape. Can we rotate them?*
Child: *No*
Researcher: *Why do you think so?*
Child: *The small gears will be stuck.*

Gear speed refers to how the size of gears influences the speed of spinning gears. Table 4 presents the types and frequency of students' alternative conceptions about gear speed. As shown, the participants misunderstood that the position, rather than the size of gears, determines the speed of gear rotation. That is, when a series of gears was horizontally arranged, either the first gear or the last one ran fast regardless of the size (see Example 4). Some children even described that the big gear ran faster than the small one did (see Example 5). Further, they might indicate that two meshing gears of different sizes might run at the same speed. That is, as long as the gears were connected, they all ran at equal speed (see Example 6). Still, some children might naïvely believe that whatever gear was attached with a crank, it might run faster than those without (see Example 7).

Table 4
Number of Students with Alternative Conceptions about Gear Speed

Gear speed	Experimental group			Control group		
	Pretest	Posttest	Delayed test	Pretest	Posttest	Delayed test
Meshed gears of the same size but with different colors have different turning speeds.	2	3	4	12	13	12
Meshed gears of different sizes have the same turning speed.	13	4	0	20	30	32
A big gear turns faster.	37	7	6	40	30	39
A gear with or without a handle turns fast.	17	17	17	18	14	20
The first gear turns faster.	31	29	24	37	35	39
The second gear turns faster.	0	0	2	1	0	1

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The last gear turns faster.	6	3	2	7	12	3
I do not know.	21	4	0	18	5	9
Total	127	67	55	153	139	155

Example 4:

Researcher:	*If I turn the three interlocking gears (big, small, and big), which one will spin fast?*
Child:	*The first one is faster.*
Researcher:	*Why do you think so?*
Child:	*Because it is placed first. The slower one is the last gear.*

Example 5:

Researcher: *There is a big gear and a small gear. Each one has a tag on it. If we align the tags and rotate the gears, which one will first complete one turn.*
Child: *The big gear.*
Researcher: *Why do you think so?*
Child: *Because it is bigger.*

Example 6:

Researcher: *Two big gears and a small gear are horizontally meshed together. Which one will rotate faster if turned?*
Child: *They rotate at the same speed.*
Researcher: *Why do you think so?*
Child: *Because they are meshed together.*

Example 7:

Researcher: *There are three interlocking gears of different sizes (big, small, and big). If I turn the crank, which one will run faster?*
Child: *The first one.*
Researcher: *Why do you think so?*
Child: *Because it has the crank attached. The second and the third ones do not have the crank, so they run slower.*

Gear direction implies that when two gears mesh, the second gear rotates in the opposite direction. Table 5 categorizes students' misconceptions about gear direction. For instance, children often believe that interlocking gears may rotate in the same direction below.

Researcher:	*When two gears are interlocked, which direction will the second one turn if rotated?*
Child:	*This side (Pointing to the first one).*
Researcher:	*The same side as the first one?*
Child:	*Yes.*
Researcher:	*Why do you think so?*
Child:	*They turn in the same direction because they are meshed together.*

Additionally, with three gears connected in a horizontal array, some children recognize that the initial two gears rotate in opposing directions. Yet, they erroneously believe that the second and final gears can rotate identically, as shown below:

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Researcher: *Three gears of the same size were interlocked. If I turn the first one to the right size, which direction will the last gear turn?*
Child: *This side (Left).*
Researcher: *Why do you think so?*
Child: *The second one and the third one turn in the same direction.*

Moreover, children's misunderstandings about gear mechanics are highlighted in two prevalent misconceptions. The first misconception is the belief that a larger gear will always rotate in a direction opposite to that of a smaller one.

Researcher: *Three gears (big, small, and big) are horizontally meshing together. If one more small gear is added in the end, which side does it turn?*
Child: *Right side.*
Researcher: *Why do you think so?*
Child: *The first gear is bigger than the last one. The big gear turns right and then the small gear turns left.*

This indicates a mistaken assumption of size-determined rotational dominance. Conversely, the second misconception is where children erroneously believe that gears of uniform size will rotate in the same direction.

Researcher: *Three gears of the same size are horizontally interlocked. If the first one turns left, in which direction do the second one and the third one rotate?*
Child: *The second one turns left and then the third one turns left, too.*
Researcher: *Why do you think so?*
Child: *The gears have the same size and so they turn in the same direction.*

This suggests a confusion regarding the effect of gear size uniformity on rotational directionality, which is a misinterpretation of the basic principle that meshing gears rotate in opposite directions. The examples underscore the fundamental misunderstandings among children regarding how gears function. In summary, according to Tables 3, 4, and 5, preschoolers in the experimental condition tended to have fewer alternative conceptions in the post-test and the delayed test compared to those in the control group. This suggested that young children learned more effectively when they were encouraged to predict, observe, and explain while playing with building blocks.

Table 5
Number of Students with Alternative Conceptions about Gear Direction

Gear direction	Experimental group			Control group		
	Pretest	Posttest	Delayed test	Pretest	Posttest	Delayed test
Meshed gears have the same turning direction.	48	22	16	55	32	51
Three gears are interlocked; the second one and the last one turn in the same direction.	5	7	3	5	6	6
Meshed gears of different sizes have different turning directions.	3	0	0	0	0	0
Meshed gears of the same size have the same turning direction.	0	0	0	0	0	2
I do not know.	12	2	6	23	20	19
Total	68	31	25	83	58	78

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Discussion

In this study, the integration of the Predict-Observe-Explain (POE) model into building block activities was examined for its potential to augment preschoolers' understanding of gear concepts. Analysis of the data presented in Figures 3 and 4 highlights the pivotal role of the POE model in fostering an enhanced understanding of gear mechanisms among preschoolers, after removing those who initially had more prior knowledge. The findings suggest that children who participated in activities integrated with the POE model outperformed their peers in the control group with regard to their scores on both the immediate post-test and the two-week follow-up assessment. Moreover, a significant reduction in alternative conceptions was identified in both the post-test and delayed test within the experimental condition. This suggests that engaging children in predicting outcomes, justifying their predictions, and actively reflecting on the differences or similarities between predictions and actual observations can substantially improve their conceptual understanding during block play activities. Conversely, the control group, despite receiving structured building instructions, experienced limited learning gains. This indicates that mere physical manipulation of gears is insufficient for fostering an in-depth exploration of gear mechanisms (Asghar et al., 2019; Chambers et al., 2008; Reuter & Leuchter, 2021). Reflection is critical in learning (Chi et al., 1989; Wilson et al., 2012). The most significant learning gains arise when children, through discussion and reflection, negotiate the meanings of their predictions, observations, and explanations, facilitated by interactions with an instructor (Chi et al., 2008; Reiser, 2004). Various studies have highlighted the POE (Predict-Observe-Explain) strategy's effectiveness in enhancing conceptual understanding among elementary students in areas such as Heat and Temperature (Karsli Baydere, 2021), light refraction (Zhao et al., 2021), and moon phase changes (Hsiao et al., 2017). Further, research by Reuter & Leuchter (2021) on 248 preschoolers involved in gear engineering tasks showed that those in guided play outperformed peers in free play. However, the intervention time in Reuter and Leuchter's (2021) study was limited to 45 minutes, which might be too short to effectively measure the complete impact of the instructional approach on the children's acquisition of gears conceptions.

The present study also found that gear speed and gear direction were complicated concepts for children to learn. The accuracy rates were around 60% (mean score divided by the number of items) and 50%, respectively, for the posttest and the delayed test in the experimental groups. Similarly, around 15% and 30% were for the control group. Prior research (Reuter & Leuchter, 2021) indicated a similar finding that children's naïve concepts of gear speed were more persistent with age than those of gear direction. In Lehrer and Schauble's (1998) study on investigating elementary school students' reasoning about gears, they found that the students' conceptions about gear speed did not improve with increasing age. That is, concepts of gear speed and gear direction were challenging for students in second and even fifth grade. Their naïve concepts included that meshed gears would always rotate in the same direction and the gears always turn at the same speed regardless of their relative size. Identically, while probing preschoolers' alternative conceptions of gears, the present study also found that some children believed that gears can still rotate as long as they are meshing together. Some thought the big gear ran faster than the small one did, while some believed that gears of different sizes never rotate in the same direction. In sum, children's alternative conceptions regarding gears are resilient and hard to change (Asghar et al., 2019; Chambers et al., 2008; Reuter & Leuchter, 2021, 2022), which may later affect their science learning. Preschool teachers need to carefully consider these alternative conceptions while designing and teaching their lessons (Asghar et al., 2019; Reuter & Leuchter, 2022). This warrants additional studies to develop effective instructional approaches for improving children's alternative conceptions.

From a theoretical perspective, in this study, the experimental group followed a constructivist teaching approach, whereas the control group employed a teacher-directed teaching process. The former emphasizes active learning through engagement, reflection, and building on prior knowledge, where learners make predictions, observe outcomes, and explain discrepancies, fostering deeper understanding. In contrast, the latter involves the direct transmission of knowledge, with learners passively receiving information through demonstrations and instructions without active reflection. The POE model's constructivist framework aligns with educational theories advocating for meaningful learning experiences, encouraging active participation and cognitive engagement, leading to robust learning (Chi, 2021; Karsli Baydere, 2021). Conversely, the teacher-directed teaching approach used in the control group lacks interactive and reflective elements essential for deep learning, often resulting in surface-level understanding. While effective in conveying procedural knowledge, teaching without active reflection does not promote the comprehensive conceptual understanding that constructivist approaches achieve.

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Significantly positive impacts of the POE model on fostering young children's playing with building blocks were identified in the present study. However, we acknowledge some study limitations. Although the treatment time was based on the evaluation of the pilot studies, some children still need more time to practice and explore the causal relationships of gear concepts. This might lead to their difficulty explaining the reasons for gear questions. Future studies, not limited to an hour to complete each activity, should provide sufficient time for young children to play with blocks, to reflect, as well as to respond to the prompts. Additionally, the participants in the present study were recruited from a rural area, including a majority of children of lower socioeconomic status. Additional research is necessary to recruit more advantaged children, which may provide additional variability and ensure better generalizability.

Conclusions and Implications

This research explored the impact of integrating the POE model into preschool learning activities on understanding gears, compared to conventional methods that rely on more reading instructional guides. The study found that children in the POE group, excluding those with more prior knowledge, performed better on both immediate and delayed tests, with fewer misconceptions about gears. These results demonstrate that the POE model not only enhances immediate comprehension but also has a lasting effect on knowledge retention. The findings underscore the significant challenge educators face in overcoming deeply rooted misunderstandings and emphasize the effectiveness of incorporating reflective instructional strategies like the POE model to counteract these persistent misconceptions.

Furthermore, the implications of this study are significant for international readers, particularly those involved in early childhood education and curriculum development. The demonstrated effectiveness of the POE model suggests a promising approach for enhancing young children's scientific understanding and overcoming persistent misconceptions. By engaging children in prediction, observation, and explanation, educators can facilitate a more profound and enduring understanding of scientific concepts. However, given the study's brief duration and limited demographic scope, future research should expand on these methods over longer periods and among a more varied group of participants. This will help to further validate and strengthen the results, ensuring their applicability and relevance on a global scale. By addressing these gaps, future studies can build on the foundational work presented here, contributing to a more comprehensive understanding of effective pedagogical strategies in early childhood science education.

Declaration of Interest

The authors declare no competing interest.

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