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Role-Play-Based Science Learning: Its Impact on the Thinking Skills of Children Aged 5–6 Years

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Abstract

Science learning during the preschool years plays an important role in fostering scientific thinking and developing children's higher-order thinking skills. Role-playing activities provide authentic learning experiences that are closely connected to children's everyday lives while promoting observation, exploration, and reflection. This study aimed to examine the effectiveness of role-play-based science learning in improving critical and creative thinking skills among children aged 5–6 years and to analyze the influence of initial thinking abilities on learning outcomes. The study employed a quasi-experimental pretest–posttest control group design involving 20 kindergarten children who were equally assigned to experimental and control groups. Data were collected using the Early Childhood Thinking Skills Inventory and analyzed through Multivariate Analysis of Covariance (MANCOVA). The findings revealed significant differences between the experimental and control groups, indicating that role-play-based science learning effectively enhanced children's critical and creative thinking skills. Further analysis showed that pretest critical thinking significantly influenced posttest outcomes, whereas pretest creative thinking did not have a significant effect. These findings suggest that role-play-based science learning is an effective approach for developing higher-order thinking skills through active, reflective, and collaborative learning experiences that align with the developmental characteristics of young children while strengthening the foundation of scientific thinking from an early age.

Keywords: *Early Childhood, Role Playing, Creative Thinking, Critical Thinking.*

Abstrak

Pembelajaran sains pada masa prasekolah berperan penting dalam membentuk pola pikir ilmiah dan mengembangkan keterampilan berpikir tingkat tinggi anak. Aktivitas bermain peran menghadirkan pengalaman belajar yang autentik, dekat dengan kehidupan sehari-hari, serta mendorong kemampuan observasi, eksplorasi, dan refleksi. Penelitian ini bertujuan mengkaji efektivitas pembelajaran sains berbasis bermain peran terhadap peningkatan kemampuan berpikir kritis dan kreatif anak usia 5–6 tahun serta menganalisis pengaruh kemampuan berpikir awal terhadap hasil belajar. Penelitian menggunakan desain quasi-experimental dengan model pretest–posttest control group yang melibatkan 20 anak taman kanak-kanak yang dibagi secara seimbang ke dalam kelompok eksperimen dan kontrol. Data dikumpulkan menggunakan Early Childhood Thinking Skills Inventory dan dianalisis melalui Multivariate Analysis of Covariance (MANCOVA). Hasil penelitian menunjukkan adanya perbedaan yang signifikan antara kelompok eksperimen dan kelompok kontrol, di mana pembelajaran sains berbasis bermain peran secara efektif meningkatkan kemampuan berpikir kritis dan kreatif anak. Analisis lebih lanjut mengungkapkan

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bahwa kemampuan berpikir kritis pada tahap pretest memberikan pengaruh dominan terhadap hasil akhir, sedangkan kemampuan berpikir kreatif awal tidak menunjukkan pengaruh yang signifikan. Temuan ini menunjukkan bahwa pembelajaran sains berbasis bermain peran merupakan pendekatan yang efektif untuk mengembangkan kemampuan berpikir tingkat tinggi melalui kegiatan belajar yang aktif, reflektif, kolaboratif, dan sesuai dengan karakteristik perkembangan anak usia dini, sekaligus memperkuat fondasi berpikir ilmiah sejak usia awal.

Keywords: Anak Usia Dini, Bermain Pera, Berpikir Kreatif, Berpikir Kritis

INTRODUCTION

Science education in early childhood plays a crucial role in establishing the foundations of children's scientific thinking and cognitive development. Early science experiences stimulate children's natural curiosity about the surrounding environment and encourage them to explore, observe, and question everyday phenomena (Alghamdi, 2023). Through meaningful interactions with their environment, children begin to develop the ability to interpret observations, construct explanations, and connect experiences with emerging scientific concepts (Sun et al., 2024). These early learning experiences provide an important foundation for future learning and contribute to children's confidence in addressing intellectual challenges (Lee et al., 2023).

Children aged 5–6 years experience rapid cognitive, linguistic, social, and motor development (Shin et al., 2023). During this period, learning activities that involve active exploration and play are particularly effective because they correspond to children's developmental characteristics. Science learning activities allow children to engage directly with objects, events, and phenomena, thereby strengthening observation skills, language development, and problem-solving abilities (Ata-Akturk & Sevimli-Celik, 2023). Recent educational trends have emphasized inquiry-based and experiential approaches that encourage children to construct knowledge through direct engagement rather than passive reception of information (Abdulla et al., 2023).

Role-play-based learning has emerged as a promising pedagogical approach for supporting young children's learning. Role-playing enables children to explore concepts through imagination, simulation, and social interaction while actively participating in learning experiences (Wang et al., 2023). In science education, role-playing can transform abstract concepts into meaningful experiences by allowing children to assume roles such as scientists, environmental observers, farmers, or explorers (Yudina & Kuzyakov, 2023). Such experiences promote engagement, collaboration, and deeper understanding because children learn through action and interaction rather than through verbal explanations alone.

The effectiveness of role-playing can be explained through developmental learning theories. Piaget's theory suggests that children in the preoperational stage learn effectively through symbolic representation and pretend play, which facilitate the

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transition from concrete experiences to emerging abstract thinking (Weber & Greiff, 2023; Verdun & Marks, 2024). Similarly, Vygotsky's concept of the Zone of Proximal Development emphasizes the importance of social interaction and scaffolding in supporting children's learning (Deng et al., 2023). Role-playing activities create opportunities for collaborative learning in which children receive support from teachers and peers while constructing knowledge through meaningful social engagement.

Previous studies have reported positive effects of role-playing on children's conceptual understanding, creativity, communication skills, and learning motivation (Wadwa et al., 2023; Siegel et al., 2025a). Research conducted in elementary education settings has shown that simulation-based activities can enhance learner engagement and improve academic performance (Zhang et al., 2023; Fridberg & Redfors, 2024). Although these findings demonstrate the educational value of role-playing, empirical evidence regarding its impact on children's thinking skills within science learning contexts remains limited. Most studies have focused on general learning outcomes rather than specific cognitive processes associated with scientific thinking, such as observation, inference, reasoning, and hypothesis formation (Goldstein & Brooks, 2023).

The need for effective science learning approaches is particularly important because many young children continue to experience difficulties understanding scientific concepts when instruction relies primarily on teacher explanations or textbook-based activities (Priyanto & Hairani, 2025). Such approaches often provide limited opportunities for exploration and experimentation, making abstract concepts difficult for children to comprehend (Fridberg & Redfors, 2024). As a result, learning outcomes frequently emphasize memorization rather than meaningful understanding and application. These limitations highlight the importance of instructional approaches that encourage active participation, inquiry, and reflective thinking.

Role-playing provides opportunities for multisensory learning experiences that involve observation, decision-making, problem-solving, and reflection (Goemans et al., 2023). Through participation in science-related scenarios, children engage in activities that require them to predict outcomes, evaluate information, and communicate ideas. These processes are closely related to the development of higher-order thinking skills, particularly critical and creative thinking (Morales-Muñoz et al., 2023). The integration of science learning and role-playing therefore has considerable potential to support cognitive development during early childhood.

Despite the growing interest in active learning approaches, empirical studies examining the effects of role-play-based science learning on children's thinking skills remain scarce, particularly in Indonesian early childhood education settings (Siegel et al., 2025b; Rodriguez-Ayllon et al., 2023). Existing research has rarely investigated how role-playing influences critical and creative thinking simultaneously within science learning environments. Additional evidence is needed to clarify the effectiveness of this instructional approach and to provide practical guidance for educators seeking to

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strengthen children's higher-order thinking skills through developmentally appropriate learning experiences.

This study examines the effectiveness of role-play-based science learning in improving critical and creative thinking skills among children aged 5–6 years. The study also investigates the influence of initial thinking abilities on post-intervention outcomes. The findings are expected to contribute empirical evidence to the field of early childhood science education and provide practical recommendations for implementing innovative learning strategies that promote active participation, inquiry, and higher-order thinking development among young children.

METHODS

Research Design

This study employed a quasi-experimental design using a pretest–posttest control group approach to examine the effectiveness of role-play-based science learning in enhancing critical and creative thinking skills among children aged 5–6 years (Gong et al., 2024). A quasi-experimental design was selected because random assignment was not feasible within the existing classroom structure. This design enabled the comparison of learning outcomes between groups while preserving the natural educational setting.

Before the intervention, both groups completed a pretest to assess their initial levels of critical and creative thinking. The experimental group then participated in role-play-based science learning activities, while the control group received conventional science instruction commonly implemented in kindergarten classrooms. After the intervention period, both groups completed a posttest using the same assessment instrument.

The intervention was conducted over six weeks, with three sessions per week and each session lasting approximately 60 minutes. Children in the experimental group participated in science-themed role-playing activities, including acting as scientists, environmental observers, weather reporters, plant researchers, and animal explorers. These activities encouraged children to observe, investigate, communicate ideas, and solve simple science-related problems. In contrast, the control group engaged in teacher-directed learning activities involving explanations, demonstrations, and question-and-answer sessions.

The independent variable was the instructional approach, consisting of role-play-based science learning and conventional science learning. The dependent variables were critical thinking and creative thinking skills. Pretest scores were treated as covariates during statistical analysis to control for baseline differences among participants.

Participants

The participants consisted of 20 children aged 5–6 years enrolled in two private kindergartens in West Sumatra, Indonesia. Participants were selected using purposive sampling to ensure that the sample reflected characteristics relevant to the objectives of the study (Nathanielsz et al., 2023). The inclusion criteria included: (a) children aged

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between 5 and 6 years, (b) regular attendance in classroom learning activities, (c) the absence of diagnosed developmental disorders that could significantly affect participation in learning activities, and (d) written parental consent for participation in the study.

The participants were equally assigned to an experimental group (n = 10) and a control group (n = 10). Demographic information was collected through a questionnaire completed by parents, including age, gender, parental educational background, previous experiences with role-playing activities, and exposure to science-related activities at home. The average age of the participants was 5.6 years, with a balanced distribution of boys and girls. No participants withdrew during the study, resulting in a retention rate of 100%.

Instrumentation

Data were collected using the Early Childhood Thinking Skills Inventory (ECTSI), which was designed to assess critical and creative thinking skills among young children through structured classroom observations. The instrument consisted of two major dimensions: critical thinking and creative thinking.

Critical thinking was measured through indicators of observation, questioning, reasoning, evidence-based explanation, and problem-solving. Creative thinking was assessed through fluency, flexibility, originality, and elaboration (Bai et al., 2023). Each item was evaluated using a four-point developmental scale ranging from 1 (Beginning Development) to 4 (Very Well Developed).

The instrument underwent content validation by three experts specializing in early childhood education, child development, and science education. The Content Validity Index (CVI) reached 0.92, indicating strong content validity. Inter-rater reliability was established through independent observations conducted by two trained raters. Additional qualitative data were obtained through field notes and classroom documentation to support the interpretation of quantitative findings.

Data Collection Procedure

Data collection was conducted in three stages: preparation, implementation, and evaluation. During the preparation stage, ethical approval was obtained from the relevant institution, and written informed consent was secured from parents or legal guardians. Teachers and observers received training regarding the implementation of role-play-based science learning and the use of the observation instrument.

Before the intervention, all participants completed a pretest assessment using the ECTSI to determine baseline levels of critical and creative thinking. The implementation stage lasted six weeks. During this period, the experimental group participated in role-play-based science learning activities three times per week. Learning scenarios included investigating weather phenomena, exploring plant growth, examining animal habitats, and conducting simple scientific investigations through

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imaginative role-play. Children were encouraged to ask questions, make predictions, test ideas, and communicate their findings with peers.

Meanwhile, the control group participated in conventional science learning activities delivered by classroom teachers using discussion, demonstration, and guided instruction methods. Throughout the intervention period, classroom observations, field notes, and documentation were collected to record children's engagement and learning behaviors. Following completion of the intervention, all participants completed a posttest using the same instrument administered during the pretest. The collected data were subsequently prepared for statistical analysis.

Data Analysis

Data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics were used to summarize participant characteristics and to describe mean scores, standard deviations, and score distributions for critical and creative thinking before and after the intervention. Prior to hypothesis testing, the assumptions of normality, homogeneity of variance, linearity, and homogeneity of covariance matrices were examined to ensure the appropriateness of multivariate analysis (De Geus et al., 2023). The primary statistical procedure employed was Multivariate Analysis of Covariance (MANCOVA).

MANCOVA was used to examine differences between the experimental and control groups on posttest critical thinking and creative thinking scores while controlling for corresponding pretest scores. This analytical approach allowed the simultaneous examination of multiple dependent variables and provided a comprehensive assessment of the effectiveness of role-play-based science learning. Statistical significance was established at the 0.05 level. All analyses were performed using Jamovi statistical software.

Quality Control and Ethical Considerations

Several procedures were implemented to ensure data quality, reliability, and ethical compliance. Prior to data collection, observers participated in training sessions to standardize observation procedures and scoring criteria. Inter-rater reliability was monitored throughout the study to ensure consistency in observations and assessments. A pilot assessment was conducted before the main study to verify the clarity, feasibility, and appropriateness of the instrument for young children. The study adhered to established ethical principles for research involving children. Written informed consent was obtained from parents or legal guardians, while verbal assent was obtained from participating children. Participation was voluntary, and children were free to withdraw from any activity without penalty.

Participant confidentiality was protected through anonymous coding procedures, and all research data were stored securely. Learning activities were designed to be safe, enjoyable, and developmentally appropriate. No physical or psychological risks were associated with participation. These procedures were implemented to ensure that the

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study produced valid, reliable, and ethically sound evidence regarding the effectiveness of role-play-based science learning in developing critical and creative thinking skills among children aged 5–6 years.

RESULTS AND DISCUSSION

Results

This study examined the effectiveness of role-play-based science learning in enhancing critical and creative thinking skills among children aged 5–6 years. A one-way Multivariate Analysis of Covariance (MANCOVA) was conducted using posttest critical thinking and posttest creative thinking scores as dependent variables, while pretest critical thinking and pretest creative thinking scores were included as covariates. Prior to the main analysis, several assumptions required for MANCOVA were examined.

Assumption Testing

Homogeneity of Covariance Matrices

The homogeneity of covariance matrices was assessed using Box's M test. The analysis produced non-estimable values (NaN), which may be attributed to the relatively small sample size and limitations in estimating stable covariance matrices. Although the Box's M statistic could not be computed, MANCOVA is generally considered robust to violations of this assumption when group sizes are balanced. Given that the experimental and control groups contained equal numbers of participants, the multivariate analysis was considered appropriate.

Table 1. Box's Homogeneity of Covariance Matrices Test

χ^2	df	p
NaN	6	NaN

Multivariate Normality

Multivariate normality was assessed using the Shapiro–Wilk multivariate test. The results indicated a non-significant value, W = .936, p = .203, suggesting that the joint distribution of the dependent variables did not significantly deviate from multivariate normality.

Table 2. Shapiro–Wilk Multivariate Normality Test

W	p
.936	.203

The Q–Q plot further supported this finding, as the observed data points closely followed the theoretical diagonal line, indicating an acceptable level of multivariate normality.

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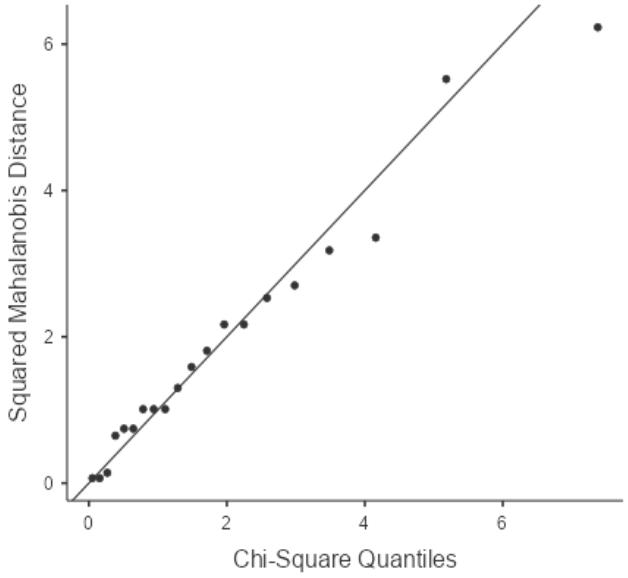

Figure 1. Q–Q Plot Assessing Multivariate Normality

Multivariate Analysis

The multivariate test results revealed a statistically significant effect of instructional group on the combined dependent variables. All multivariate statistics consistently indicated a significant difference between the experimental and control groups.

Table 3. Multivariate Test Results

Effect	Statistic	Value	F	df1	df2	p
Group	Pillai's Trace	.9597	6.920	4	30	< .001
	Wilks' Lambda	.0547	22.932	4	28	< .001
	Hotelling's Trace	17.020	55.314	4	26	< .001
	Roy's Largest Root	17.004	127.531	2	15	< .001

The significant multivariate effect indicates that role-play-based science learning produced meaningful improvements in the overall thinking skills of children. Roy's Largest Root showed the strongest effect, $F(2,15) = 127.531$, $p < .001$, providing strong evidence that the instructional approach influenced the combined outcomes of critical and creative thinking. Pretest creative thinking did not significantly affect the combined posttest outcomes, as reflected by non-significant values across all multivariate statistics ($p = .502$). In contrast, pretest critical thinking demonstrated a significant multivariate effect, Pillai's Trace = .9099, $F(2,14) = 70.678$, $p < .001$, indicating that initial critical thinking ability served as an important predictor of subsequent performance.

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Univariate Analysis

To identify the specific effects of the intervention on each dependent variable, follow-up univariate analyses were conducted.

Table 4. Univariate Test Results

Effect	**Dependent Variable**	**F**	**p**
Group	Posttest Critical Thinking	127.500	< .001
Group	Posttest Creative Thinking	15.449	< .001
Pretest Creative Thinking	Posttest Critical Thinking	0.701	.415
Pretest Creative Thinking	Posttest Creative Thinking	1.320	.269
Pretest Critical Thinking	Posttest Critical Thinking	147.469	< .001
Pretest Critical Thinking	Posttest Creative Thinking	4.633	.048

The instructional group significantly influenced both critical thinking and creative thinking outcomes. The effect was particularly strong for critical thinking, $F(2,15) = 127.500$, $p < .001$, compared with creative thinking, $F(2,15) = 15.449$, $p < .001$. These findings indicate that role-play-based science learning was effective in improving both domains of thinking, with a greater impact on critical thinking.

Pretest creative thinking did not significantly predict either posttest critical thinking or posttest creative thinking. Conversely, pretest critical thinking significantly predicted both posttest critical thinking and posttest creative thinking. This finding suggests that children with stronger initial analytical abilities tended to achieve higher levels of performance following the intervention.

The MANCOVA results demonstrate that role-play-based science learning significantly enhanced critical and creative thinking skills among children aged 5–6 years. The intervention exerted a stronger influence on critical thinking than on creative thinking, while initial critical thinking ability emerged as an important predictor of learning outcomes. These findings provide empirical support for the use of role-playing activities as an effective strategy for promoting higher-order thinking skills in early childhood science education.

Discussion

The findings demonstrated that role-play-based science learning significantly improved both critical and creative thinking skills among children aged 5–6 years. The multivariate analysis revealed a strong effect of the instructional approach on the combined thinking outcomes, indicating that children who participated in role-playing science activities achieved higher levels of cognitive performance than those who experienced conventional instruction. The effect was particularly pronounced for critical thinking, suggesting that role-play provides an effective context for developing observation, reasoning, questioning, and evidence-based explanation skills during early childhood.

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The stronger improvement in critical thinking may be explained by the nature of role-play-based science activities. Throughout the intervention, children actively engaged in observing phenomena, discussing possible explanations, predicting outcomes, and evaluating observations within meaningful social contexts. These experiences encouraged children to move beyond passive reception of information and become active participants in knowledge construction. From a constructivist perspective, learning occurs when children interact directly with their environment and organize experiences into meaningful cognitive structures. The present findings support this view by showing that children developed higher levels of analytical thinking when scientific concepts were embedded within imaginative and socially interactive activities.

The results are also consistent with Vygotsky's sociocultural theory, which emphasizes the importance of social interaction in cognitive development. Role-playing activities required children to communicate ideas, negotiate meanings, ask questions, and collaborate with peers while exploring scientific concepts. Such interactions may have created opportunities for cognitive scaffolding, allowing children to perform at higher levels than they could independently. The collaborative nature of role-play appears to have supported the development of reasoning skills by encouraging children to articulate their thinking and respond to alternative viewpoints presented by peers.

Although the intervention produced a stronger effect on critical thinking, significant improvements were also observed in creative thinking. Children exposed to role-play-based science learning demonstrated greater flexibility in generating ideas, proposing alternative explanations, and imagining different solutions to simple scientific problems. These findings suggest that science learning does not need to be limited to factual knowledge acquisition. When scientific exploration is integrated with imaginative play, children are encouraged to combine logical reasoning with creative expression. Such integration may be particularly valuable during early childhood, a developmental period characterized by high levels of curiosity, imagination, and exploratory behavior.

An important finding of this study is that pretest critical thinking significantly predicted both posttest critical thinking and posttest creative thinking, whereas pretest creative thinking did not significantly predict subsequent outcomes. This pattern suggests that analytical thinking may provide a foundation for broader cognitive development. Children who already possessed stronger reasoning abilities appeared better prepared to benefit from exploratory learning experiences and to generate novel ideas based on their observations. The finding supports previous research indicating that critical and creative thinking are not independent processes but rather complementary dimensions of higher-order thinking. Analytical reasoning may facilitate the evaluation, refinement, and expansion of creative ideas, resulting in more effective problem-solving and knowledge construction.

The findings are generally consistent with previous studies reporting positive effects of role-play and play-based learning on children's cognitive development, scientific inquiry skills, and problem-solving abilities. Previous research has shown that

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role-playing activities can enhance children's engagement, motivation, and conceptual understanding by connecting abstract concepts with concrete experiences. The present study extends this body of knowledge by demonstrating that role-play-based science learning contributes simultaneously to both critical and creative thinking among preschool children. This contribution is particularly relevant because empirical evidence examining these two dimensions together within early childhood science education remains limited.

From a practical perspective, the findings highlight the value of integrating role-playing activities into science learning environments. Early childhood educators may use role-play scenarios involving scientists, environmental explorers, weather observers, or animal researchers to create meaningful learning experiences that promote inquiry and reflection. Such activities provide opportunities for children to investigate questions, communicate observations, and develop explanations while maintaining the playful nature of early childhood learning. The results suggest that science education in preschool settings can move beyond teacher-centered approaches toward more interactive and child-centered pedagogies that support higher-order thinking development.

Several limitations should be acknowledged. First, the relatively small sample size limits the generalizability of the findings to broader populations. Second, the study relied primarily on observational assessments, which may be influenced by observer interpretation despite efforts to ensure reliability. Third, the intervention was conducted over a relatively short period, preventing examination of long-term effects on cognitive development. Future research may involve larger and more diverse samples, employ longitudinal designs, and investigate additional factors such as family support, classroom climate, and teacher practices that may influence the effectiveness of role-play-based science learning.

The findings provide evidence that role-play-based science learning represents an effective pedagogical approach for promoting higher-order thinking in early childhood education. By combining scientific inquiry, imaginative play, and social interaction, this approach creates meaningful learning experiences that support both analytical and creative dimensions of cognition. The study contributes to the growing literature on play-based science education and reinforces the importance of developmentally appropriate learning environments that encourage children to explore, question, and construct knowledge actively.

CONCLUSION

Role-play-based science learning was effective in enhancing the critical and creative thinking skills of children aged 5–6 years. Children who participated in role-playing science activities demonstrated significantly better posttest performance than those who received conventional instruction. The findings showed a stronger effect on critical thinking than on creative thinking, while pretest critical thinking emerged as a significant predictor of learning outcomes. These results suggest that role-playing

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activities provide meaningful opportunities for observation, inquiry, problem-solving, and idea generation through active engagement with scientific concepts. The study contributes to the growing evidence that play-based approaches support higher-order thinking development in early childhood and offers practical implications for educators seeking to create interactive learning environments that foster scientific literacy, curiosity, and cognitive growth.

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