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The Effectiveness of the SEMAI Nature-Based Project Model in Enhancing Early Childhood Critical Thinking Skills

Yuli Pujianti [1]✉, Endang Komara [2], Hidayat [3], Agus Mulyanto [4]

[1] Early Childhood Islamic Education, STAI Al-Marhalah Al-'Ulya Bekasi, Indonesia
[2,4] Doctor of Educational Science, Universitas Islam Nusantara, Indonesia
[3] Master of Government Science, Universitas Jenderal Achmad Yani, Indonesia

ABSTRACT

Critical thinking should be cultivated from early childhood through learning experiences that enable children to question, observe, compare, reason, decide, and reflect. However, nature-based and project-based activities in early childhood settings are often implemented as isolated or product-oriented tasks without a systematic cycle of planning, assessment, and improvement. This study examined the effectiveness of the SEMAI Nature-Based Project Model in enhancing the critical thinking skills of children aged 5–6 years. A quantitative one-group pretest-posttest design involved 60 children from State Kindergarten 1 Bekasi and Bunga Bangsa Islamic School Bekasi. Data were collected using a validated structured observation rubric comprising 12 critical thinking indicators and analyzed using descriptive statistics, the Wilcoxon Signed-Rank Test, and standardized effect sizes. The results showed significant increases in critical thinking scores at both institutions ($Z = -4.790$, $p < .001$), with a large effect size ($r = .87$). All children obtained higher posttest scores, and improvements occurred across all indicators. The largest gains were found in identifying simple cause-and-effect relationships and drawing conclusions from observations or experiments. The novelty of SEMAI lies in integrating nature-based projects into a strategic, cyclical instructional framework comprising Prepare, Envision, Mobilize, Apply, and Iterate. This structure transforms project activities into a coherent process of inquiry, evidence generation, reflection, and continuous improvement. Early childhood educators are recommended to use SEMAI to design purposeful nature-based projects, employ open-ended questioning, and assess critical thinking through authentic observation. Future studies should include comparison groups, longer interventions, and follow-up assessments.

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.CONTACT Corresponding Author: Yuli Pujianti, STAI Al-Marhalah Al-'Ulya Bekasi, Indonesia Email: yuli@almarhalah.ac.id

1. Introduction

The transformation of education in the twenty-first century has increasingly emphasized the importance of developing learners' ability to think critically, solve problems, communicate ideas, collaborate with others, and make reflective decisions from the earliest stages of education. In early childhood education, critical thinking does not take the form of formal logical argumentation, as is commonly expected of older learners. Instead, it is reflected in children's ability to ask questions, observe objects and events, compare phenomena, express simple reasons, make predictions, choose solutions, and communicate conclusions based on direct experience. Therefore, early childhood learning should focus not only on mastering basic academic content but also on developing thinking habits that enable children to explore, reason, and reflect on their surroundings. Previous studies have emphasized that early childhood education plays an essential role in shaping children's cognitive, social, emotional, and learning dispositions, including curiosity, reasoning, and problem-solving abilities (Aryani et al., 2024; Darling-Hammond et al., 2020; Johnstone et al., 2022; Pholphirul, 2016; Priadi & Fatria, 2024; Yelland, 2018).

Critical thinking in early childhood emerges most effectively when educators intentionally design meaningful, authentic experiences that promote children's questioning, reasoning, and participation. Rooted in real-world interaction, through play, dialogue, exploration, and sensory engagement, critical thinking thrives as children compare results, explain observations, and construct understanding in their own words. Key indicators include a child's curiosity, exploratory behavior, language development, and awareness of simple problems. When given opportunities to use their knowledge and language in authentic contexts, young children demonstrate early critical thinking, consistent with established research (Marchant et al., 2019; Pujianti et al., 2025; Rohita et al., 2025; Schachter et al., 2016; Yuliantina, 2025).

However, learning practices in early childhood education institutions often remain fragmented, routine-based, and limited to short-term activities. Many classroom activities are designed as isolated tasks that prioritize completion of products rather than the development of children's reasoning processes. In some contexts, kindergarten learning is also increasingly influenced by academic readiness demands, which may reduce opportunities for children to engage in open inquiry, exploration, prediction, and reflection (Bassok et al., 2016; Markowitz et al., 2020) (Bassok et al., 2016; Markowitz et al., 2020). Teachers may provide activities that are enjoyable and thematic, but not always structured to help children identify problems, examine evidence, justify answers, or draw conclusions from their own observations. As a result, the development of critical thinking in early childhood may remain incidental rather than intentionally planned and systematically evaluated. This condition indicates the need for a learning model that integrates meaningful experiences, structured inquiry, teacher facilitation, and assessment of children's critical-thinking indicators.

Project-Based Learning has been widely recognized as a promising approach to support active, meaningful, and collaborative learning. PjBL encourages learners to investigate real problems, work together, produce meaningful outcomes, and connect learning with authentic contexts. In early childhood education, project-based learning can support children's engagement because it allows them to explore topics that are close to their daily lives and to construct knowledge through direct participation. Previous studies have shown that project-based learning can enhance student engagement, inquiry, collaboration, and problem-solving when it is supported by clear learning objectives, teacher guidance, and structured learning activities (Almulla, 2020; Arndt et al., 2018; Gunarti et al., 2020; Hapidin et al., 2023; Kokotsaki et al., 2016). Nevertheless, existing PjBL models are often presented in a broad and general form, and their implementation in early childhood settings may still be limited to thematic projects or product-oriented activities. In many cases, PjBL does not explicitly provide a management cycle that guides teachers from readiness analysis, formulation of inquiry direction, resource mobilization, implementation, reflection, and improvement. Moreover, PjBL models do not always specify how children's critical thinking indicators should be stimulated and observed during each stage of learning.

Nature-based learning is another relevant approach for early childhood education because the natural environment provides concrete, dynamic, and meaningful phenomena for children to investigate. Plants, soil, water, weather, insects, leaves, stones, and other natural materials can stimulate children's observation, comparison, classification, prediction, and causal reasoning. Through nature-based activities, children can directly observe changes, test simple assumptions, and draw conclusions from visible evidence. Previous studies have demonstrated that nature-based learning can support children's cognitive, social, emotional, physical, and environmental development (Feriver et al., 2019; Johnstone et al., 2022; Kuo et al., 2023; Marchant et al., 2019; Traynor et al., 2022; Zucca et al., 2023). Nature-based activities also provide opportunities for children to experience learning beyond the classroom and to connect knowledge with real-life phenomena (Speldewinde & Campbell, 2024; Syarah et al., 2022; Trina et al., 2024). However, similar to PjBL, nature-based learning is often implemented as outdoor play, environmental exploration, or thematic activity without a sufficiently structured model for managing learning objectives, resources, teacher facilitation, reflection, and evaluation. Therefore, the potential of nature-based learning to develop critical thinking may not be fully optimized when it is not supported by a systematic pedagogical framework.

The research gap addressed in this study lies in the limited integration among Project-Based Learning, nature-based learning, strategic learning management, and explicit development of early childhood critical thinking. Existing PjBL models emphasize authentic projects and active learning, while nature-based learning emphasizes interaction with the natural environment. However, few models provide a structured, cyclical framework that guides teachers in planning, organizing, implementing, reflecting on, and improving nature-based projects specifically to enhance young children's critical thinking skills. Previous research has highlighted the importance of sustainable learning, instructional design, teacher facilitation, and systematic evaluation in improving the quality of learning (Ben-Eliyahu, 2021; Darling-Hammond et al., 2020; Herodotou, 2017). Studies on strategic management also emphasize the importance of readiness analysis, resource mobilization, environmental scanning, implementation control, and continuous improvement in achieving organizational and program goals (Alnoukari, 2021; Cheng et al., 2014; Mathooko & Ogutu, 2015). Yet these principles have not been sufficiently translated into an operational learning model for early childhood nature-based projects that focuses on transforming critical thinking.

The SEMAI Nature-Based Project Model is proposed to respond to this gap. Unlike general Project-Based Learning models, the SEMAI Model is structured as a learning management cycle comprising

Prepare, Envision, Mobilize, Apply, and Iterate. The Prepare stage emphasizes identifying children's readiness, learning needs, environmental resources, and relevant nature-based project themes. The Envision stage guides teachers and children to formulate inquiry directions, key questions, and expected learning outcomes. The Mobilize stage focuses on organizing tools, materials, groups, safety rules, teacher roles, and learning resources. The Apply stage provides opportunities for children to conduct observations, experiments, comparisons, discussions, and problem-solving activities through direct interaction with nature. The Iterate stage emphasizes reflection, feedback, drawing conclusions, and refining learning experiences. This cycle distinguishes SEMAI from conventional PjBL: it does not merely ask children to complete a project; rather, it manages the entire learning process so that children's questioning, reasoning, decision-making, and reflective abilities can be intentionally developed and observed.

The novelty of the SEMAI Model can be captured in four key aspects. First, SEMAI merges nature-based and project-based learning into a single coherent model that uses natural phenomena as the primary catalyst for inquiry. Second, SEMAI embeds a strategic management perspective into early childhood pedagogy by prioritizing planning, resource alignment, execution, reflection, and continuous enhancement. This quality expands the teacher's function beyond facilitator to designer, manager, and evaluator of the learning process. Third, SEMAI deliberately aligns each project phase with indicators of early childhood critical thinking, such as formulating questions, identifying problems, discerning cause and effect, constructing rationales, evaluating options, making inferences, justifying decisions, and engaging in collaborative discussion. Fourth, SEMAI incorporates an iterative phase, setting it apart from traditional linear projects; learning continues beyond initial activities as children revisit observations, compare results, share ideas, and deepen their understanding. This cyclical process aligns with the principle that sustained learning depends on feedback, reflection, and ongoing refinement (Agarwal & Selen, 2009; Cronin de Chavez et al., 2024; Herodotou, 2017).

Based on this rationale, the SEMAI Model is expected to provide a more systematic and measurable approach for enhancing early childhood critical thinking skills through nature-based projects. The model is particularly relevant for children aged 5–6 years because, at this stage, they can engage in simple observation, verbal explanation, collaborative activity, and basic reasoning when teachers provide appropriate scaffolding. The use of structured observation and critical thinking assessment indicators is important because young children express critical thinking through actions, language, choices, and social participation rather than through abstract written argumentation. Therefore, the effectiveness of the SEMAI Model needs to be empirically examined by comparing children's critical thinking skills before and after the intervention. A pretest-posttest design is suitable for identifying changes within the same group, particularly in early childhood education contexts where the use of strict control groups may face ethical and institutional challenges (Harris & Hardin, 2013; Markowitz et al., 2020; Shieh et al., 2007).

Accordingly, this study aims to examine the effectiveness of the SEMAI Nature-Based Project Model in enhancing early childhood critical thinking skills. Specifically, the study investigates whether children's critical thinking scores improve after participating in nature-based project learning structured through the SEMAI stages. This study contributes theoretically by strengthening the integration of Project-Based Learning, nature-based learning, and strategic learning management in early childhood education. It also contributes practically by offering teachers an operational model for designing, implementing, and evaluating nature-based projects that intentionally stimulate children's critical thinking. By emphasizing the novelty of SEMAI as a structured, reflective, and management-oriented model, this study is expected to provide a meaningful contribution to the development of early childhood pedagogy that is concrete, contextual, measurable, and sustainable.

2. Method

2.1 Research Design

This study was part of a research and development project to develop and test the SEMAI Nature-Based Project Model to enhance early childhood critical thinking skills. The development procedure was adapted from Borg and Gall's educational research and development model. In the larger development process, the model was implemented through six modified stages: needs analysis, model design, expert validation, limited trial, effectiveness testing, and finalization and dissemination. These stages were used to ensure that the model was theoretically grounded, practically applicable, and empirically tested in early childhood education settings.

The effectiveness phase reported in this article employed a quantitative one-group pretest-posttest design. This design was used to compare children's critical thinking scores before and after the

implementation of the SEMAI Nature-Based Project Model. The design was considered suitable because the study was conducted in natural early childhood education settings where the formation of strict control groups was limited by ethical and institutional considerations. Therefore, changes in children's critical thinking skills were examined by comparing pretest and posttest scores from the same participants.

2.2 Participants and Research Setting

The study took place at two early childhood education institutions in Bekasi City: State Kindergarten 1 Bekasi and Bunga Bangsa Islamic School (BBIS) Bekasi. These were purposively selected to represent different contexts. State Kindergarten 1 is a public school with structured management and green areas, while BBIS Bekasi is a private Islamic school with an integrated curriculum and outdoor facilities.

The participants consisted of 60 Group B children aged 5–6 years and four classroom teachers. Each institution contributed 30 children and two teachers. The teachers held undergraduate qualifications in early childhood education, and some had participated in training on implementing the Merdeka Curriculum. During the intervention, teachers acted as learning facilitators and observers. The children were selected because they were in the developmental stage in which early critical thinking skills, such as observing, questioning, giving reasons, identifying problems, choosing solutions, and collaborating, begin to develop significantly.

2.3 SEMAI Nature-Based Project Intervention

The intervention used the SEMAI Nature-Based Project Model, which has five connected stages: Prepare (teachers identify children's readiness, environmental resources, safety, and project themes), Envision (teachers and children build on the preparation to develop questions, predictions, and objectives), Mobilize (teachers organize materials, tools, and groups needed for applying these plans), Apply (children use gathered materials for observations, experiments, comparisons, discussions, and problem-solving based on earlier planning), and Iterate (children reflect on their findings from the application stage, compare results, communicate, and make simple conclusions, closing the project cycle). Each stage informs and supports the next, linking preparation, action, and reflection.

The intervention was conducted through nature-based project activities that involved concrete experiences, such as observing plants, water, soil, shadows, wind, or small animals in the school environment. Teachers did not directly answer children's questions; instead, they used open-ended questions and prompts to guide children in observing evidence, explaining reasons, making decisions, and communicating their thinking.

2.4 Instrument Development

The main instrument in this study was a structured observation rubric for assessing early childhood critical thinking. This instrument was developed through research and development steps: needs analysis, theoretical review, model design, expert validation, and field try-out. It was designed as an authentic assessment tool because critical thinking in early childhood is better observed through children's actions, verbal expressions, choices, interactions, and responses during learning activities than through written tests.

The broader rubric framework was developed based on the principles of authentic assessment, developmentally appropriate practice, holistic evaluation, continuous assessment, and individual child development. The instrument covered critical-thinking dimensions related to questioning and exploration; identification and analysis; evaluation; synthesis and conclusion; communication and collaboration; and reflective thinking. For the effectiveness test reported in this article, the observation scores were standardized into 12 critical thinking indicators: (1) asking questions about observed phenomena, (2) showing initiative to explore new objects or situations, (3) recognizing problems in everyday situations, (4) explaining problems in simple words, (5) identifying simple cause-and-effect relationships, (6) questioning the truth of information, (7) giving reasons for opinions, (8) choosing the best solution from several alternatives, (9) drawing conclusions from observations or experiments, (10) explaining reasons behind decisions, (11) explaining thought processes to others, and (12) actively participating in group discussions.

The instrument was used during both the pretest and posttest. The pretest was administered before the SEMAI intervention to assess children's initial critical-thinking skills, and the posttest was administered after the intervention using the same rubric and scoring criteria. Learning documentation, including children's work, teacher field notes, and activity documentation, was also used to support the interpretation of the observation data.

2.5 Validity of the Instrument

Instrument validity was established through content validation by expert judgment and empirical testing. Expert judgment involved three independent specialists: one in early childhood education and PAUD management, one in language, and one in instructional media. The materials and management expert reviewed the model's structure, the relevance of the SEMAI stages, and its suitability for early childhood education. The language expert assessed the clarity, readability, and appropriateness of the language used in the model and supporting materials. The media expert examined the visual design, usability, and instructional aspects of the SEMAI products.

The content validity of the instrument and model products was analyzed using Aiken's V. Expert validation employed a four-point rating scale. The results showed that the material expert obtained an Aiken's V value of 0.882 for 17 evaluated items, the media expert obtained an Aiken's V value of 0.833 for 10 evaluated items, and the language expert obtained an Aiken's V value of 0.933 for 10 evaluated items. These values fell within the high-validity category, indicating that the SEMAI instrument and supporting products were valid and appropriate for use in field testing.

Empirical validity was also conducted before the instrument was used in the effectiveness phase. The empirical try-out involved 30 respondents. The validity of the observation items was analyzed using Pearson product-moment correlation in SPSS. An item was considered valid when the obtained correlation coefficient was higher than the critical r-table value, and the significance value was lower than 0.05. The empirical validity procedure was used to ensure that the instrument measured the intended construct of early childhood critical thinking.

2.6 Reliability of the Instrument

Reliability testing was conducted to assess the instrument's consistency. The instrument's reliability was analyzed using Cronbach's alpha in SPSS. The reliability criterion used in this study was a coefficient range of 0.70–0.90, indicating high reliability. This procedure was used to determine whether the observation rubric yielded consistent scores when assessing children's critical thinking skills.

Because the instrument was observational, we strengthened reliability through careful observer preparation and scoring calibration. Facilitators and observers learned about SEMAI stages, critical-thinking indicators, behavioral descriptors, and four-level scoring criteria. Before data collection, observers discussed each indicator's meaning and practiced using the rubric. This preparation aimed to reduce subjectivity and ensure they scored consistently during pretest and posttest.

2.7 Scoring Procedures

Each indicator was assessed using a four-point scale: 1=Not Yet Developed, 2=Beginning to Develop, 3=Developing as Expected, 4=Very Well Developed. This scoring system was used for all indicators in both the pretest and the posttest. The 12 indicators produced total scores from 12 to 48; higher scores showed stronger critical thinking. Scoring depended on the frequency and quality of observed behaviors during learning. For example, silent children scored lower, while those who asked relevant questions, cited evidence, and explained observations scored higher. Skills such as exploring, problem identification, reasoning, solution selection, conclusion drawing, and participation were scored by rubric descriptors.

2.8 Observer Training and Data Collection Control

Observer preparation occurred before the pretest and intervention, focusing on understanding the SEMAI Nature-Based Project Model, recognizing indicators of early childhood critical thinking, and applying the scoring rubric consistently. Teachers and observers reviewed behavioral examples for each score level and discussed how to record observations during natural activities without interrupting children's learning. During data collection, observers focused on children's actual behaviors and verbal responses. They were instructed not to score children based on general impressions but on observable evidence, such as questions children asked, explanations given during discussions, responses to natural phenomena, choices made during problem-solving activities, and participation in group work. Field notes and documentation were used to support the observation scores and to provide contextual information about children's learning processes.

2.9 Data Analysis

The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to present the mean, minimum, maximum, and changes in scores between pretest and posttest. The normality of the paired data was examined before selecting the inferential test. Because the paired data did not meet the assumption of normality and the scores were derived from ordinal structured observation

ratings, the Wilcoxon Signed-Rank Test was chosen as it is suitable for comparing paired non-normally distributed or ordinal data to examine the significance of differences between pretest and posttest scores. Furthermore, the significance level was set at 0.05. A significance value lower than 0.05 indicated a statistically significant difference between children's critical thinking scores before and after the implementation of the SEMAI Nature-Based Project Model. To further support the findings, the analysis was conducted separately for each institution to examine the consistency of the model's effectiveness across early childhood education contexts.

3. Result And Discussion

3.1. Result

This study examined changes in the critical thinking skills of 60 children aged 5–6 years after participating in the SEMAI Nature-Based Project Model. The effectiveness test involved 30 children from State Kindergarten 1 Bekasi and 30 children from Bunga Bangsa Islamic School (BBIS) Bekasi. Critical thinking was assessed before and after the two-week intervention using a structured observation instrument consisting of 12 indicators. The possible total score ranged from 12 to 48, with higher scores representing stronger critical thinking performance.

The descriptive results showed a substantial increase in critical thinking scores at both institutions. At State Kindergarten 1 Bekasi, the mean score increased from 25.90 (SD = 1.73) in the pretest to 42.20 (SD = 2.23) in the posttest. The median increased from 25.50 to 43.00. Pretest scores ranged from 24 to 29, whereas posttest scores ranged from 38 to 45. Thus, the lowest posttest score was nine points higher than the highest pretest score, indicating a clear separation between the score distributions before and after the intervention.

A similar pattern was observed at BBIS Bekasi. The mean pretest score was 27.30 (SD = 2.22), which increased to 43.30 (SD = 0.88) in the posttest. The median shifted from 27.00 to 43.00. The pretest scores ranged from 24 to 32, while the posttest scores ranged from 42 to 46. As in State Kindergarten 1 Bekasi, there was no overlap between the pretest and posttest score ranges. The decrease in posttest score dispersion at BBIS also indicates that the children's achievement became more homogeneous at a relatively high level after the intervention.

Table 1. Descriptive Statistics of Pretest and Posttest Critical Thinking Scores

Institution	N	Pretest M (SD)	Pretest Median	Pretest Range	Posttest M (SD)	Posttest Median	Posttest Range	Mean Gain	Increase from Pretest
State Kindergarten 1 Bekasi	30	25.90 (1.73)	25.50	24–29	42.20 (2.23)	43.00	38–45	16.30	62.93%
Kindergarten BBIS Bekasi	30	27.30 (2.22)	27.00	24–32	43.30 (0.88)	43.00	42–46	16.00	58.61%

At State Kindergarten 1 Bekasi, the mean gain was 16.30 points, a 62.93% increase relative to the mean pretest score, raising the average from 53.96% to 87.92% of the maximum possible score. At BBIS Bekasi, the mean gain was 16.00 points, a 58.61% increase over the pretest mean, increasing the average from 56.88% to 90.21% of the maximum possible score. This shows that despite different initial scores and institutional characteristics, both institutions achieved similar improvements, as reflected in gains and percentage increases.

Before the inferential analysis, the normality of the paired scores was examined using the Shapiro–Wilk test. Because the pretest and posttest data did not meet the assumption of normality, differences between the paired observations were analyzed using the Wilcoxon Signed Rank Test. The rank analysis showed that all 30 children at State Kindergarten 1 Bekasi obtained higher posttest scores than pretest scores. There were 30 positive ranks, no negative ranks, and no ties. The same result was obtained at BBIS Bekasi, where all 30 children showed an increase, and none showed a decrease or an unchanged score.

The Wilcoxon Signed-Rank Test gave a Z of −4.790 for both places, with $p < .001$. Thus, the pretest-posttest score differences were significant at both sites. The probability values indicate that the increases in scores were unlikely to have occurred by chance.

To determine the magnitude of the change, we calculated the standardized Wilcoxon effect size ($r = |Z|/\sqrt{N}$), with N as the number of non-zero paired observations. The effect size was r = .87 for both

State Kindergarten 1 Bekasi and BBIS Bekasi, indicating a large effect. Thus, the evidence shows not only statistically significant differences but also practical changes of considerable magnitude after the SEMAI intervention.

Table 2. Wilcoxon Signed Rank Test and Effect Size

Institution	N	Positive Ranks	Negative Ranks	Ties	Z	*p*	Effect Size (*r*)	Interpretation
State Kindergarten 1 Bekasi	30	30	0	0	−4.790	< .001	.87	Large
Kindergarten BBIS Bekasi	30	30	0	0	−4.790	< .001	.87	Large

Analysis at the indicator level provided a more detailed picture of the children's development. Notably, all 12 critical-thinking indicators increased following the implementation of the SEMAI Nature-Based Project Model. Before the intervention, the indicator means ranged from 2.05 to 2.25, showing that most observed skills were within the Beginning to Develop category. Following the intervention, the means increased to a range of 3.55 to 3.74, indicating a shift toward the Developing as Expected and Very Well Developed levels.

Table 3. Changes in Critical Thinking Skills by Indicator

No.	Critical Thinking Indicator	Pretest Mean	Posttest Mean	Mean Gain
1	Asking questions about observed phenomena	2.20	3.63	+1.43
2	Showing initiative to explore new objects or situations	2.23	3.70	+1.47
3	Recognizing problems in everyday situations	2.10	3.55	+1.45
4	Explaining problems in simple words	2.15	3.60	+1.45
5	Identifying simple cause-and-effect relationships	2.05	3.72	+1.67
6	Questioning the accuracy of information	2.18	3.58	+1.40
7	Giving reasons for opinions	2.12	3.65	+1.53
8	Choosing the best solution from several alternatives	2.08	3.61	+1.53
9	Drawing conclusions from observations or experiments	2.14	3.74	+1.60
10	Explaining the reasons behind decisions	2.06	3.55	+1.49
11	Explaining thought processes to others	2.20	3.62	+1.42
12	Actively participating in group discussions	2.25	3.68	+1.43

The largest improvement occurred in identifying simple cause-and-effect relationships, which increased by 1.67 points. The second-largest gain occurred in drawing conclusions from observations or experiments, with an increase of 1.60 points. These two indicators represent analytical and reflective dimensions of early critical thinking. The results indicate that children became more capable of connecting an observed change with a possible cause and using evidence from an activity to formulate a simple conclusion.

Substantial improvements were also observed in giving reasons for opinions and choosing the best solution from several alternatives, both of which increased by 1.53 points. The ability to explain reasons behind decisions increased by 1.49 points, while initiative in exploring new objects or situations increased by 1.47 points. These results show that the improvement was not limited to children's ability to observe natural phenomena. It also included reasoning, evaluating alternatives, decision-making, and explaining choices.

The smallest increase occurred in questioning the accuracy of information, with a gain of 1.40 points. Nevertheless, this indicator also demonstrated a clear positive change. Questioning information may require a more advanced level of metacognitive awareness because children need to consider whether an explanation is accurate rather than merely recalling or describing what they observe. The improvement in this indicator suggests that the children began to demonstrate early evaluative thinking, although this skill may require longer and repeated learning experiences to develop further.

The observational records corroborated the quantitative changes in scores. Before the intervention, children's questions were generally factual, and their explanations frequently depended on teacher guidance. After participating in the SEMAI activities, the children demonstrated more systematic observation, formulated more relevant questions, compared the results of simple experiments, and provided elementary

reasons for their answers. During group activities, they were also more willing to communicate findings, listen to different opinions, and participate in drawing collective conclusions.

Overall, three complementary findings demonstrate the effectiveness of the SEMAI Nature-Based Project Model. First, the descriptive statistics showed substantial increases in mean and median scores, with no overlap between pretest and posttest score ranges. Second, the Wilcoxon analysis showed statistically significant improvements, with all 60 participating children obtaining higher posttest scores. Third, the large effect sizes of r = .87 at both institutions demonstrated that the improvement was not only statistically significant but also educationally substantial. The consistent changes across institutions and across all critical thinking indicators provide evidence that the SEMAI Model was associated with meaningful improvements in early childhood critical thinking skills.

4. Discussion

The findings provide evidence that the SEMAI Nature-Based Project Model was associated with a substantial improvement in early childhood critical thinking skills. The large standardized Wilcoxon effect size obtained at both institutions (r = 0.87) indicates that the difference between the pretest and posttest was not only statistically significant but also educationally meaningful. More importantly, the pattern of improvement across the indicators provides insight into how the model supported children's thinking. The greatest gains occurred in identifying simple cause-and-effect relationships (+1.67) and drawing conclusions from observations or experiments (+1.60), whereas relatively smaller, although still meaningful, gains occurred in questioning the accuracy of information (+1.40) and explaining thought processes to others (+1.42). This uneven pattern suggests that SEMAI did not influence all dimensions of critical thinking in the same way. Indicators closely connected to concrete observation and direct experimentation developed more rapidly than those requiring metacognitive judgment, epistemic evaluation, and extended verbal explanation.

The greatest improvement in identifying cause-and-effect relationships can be explained by the characteristics of the nature-based projects used in the SEMAI Model. Natural phenomena provide observable sequences in which an action or condition is followed by a visible change. For example, children can compare watered and unwatered plants, observe the movement of water, examine changes in soil texture, or notice how light affects shadows. These activities make causal relationships perceptually accessible because children can directly observe what changes, when it changes, and under what conditions. Rather than receiving a verbal explanation of causality, children encounter evidence through their own actions.

This finding is consistent with Dewey's, concept of learning through experience, in which understanding develops when learners act upon their environment and reflect on the consequences of their actions (Dewey, 2022; Quay, 2019; Thomassen & Jørgensen, 2021). In SEMAI, direct experience is not treated as an isolated activity. It is connected to questions, predictions, observations, and reflection. This organization enables children to move from simply noticing a phenomenon to considering why it occurs. Kolb's, experiential learning cycle also helps explain this process (Gemmell & Kolb, 2020; Healey & Jenkins, 2000; Kolb & Kolb, 2005). Concrete experience occurs when children manipulate objects or observe natural events; reflective observation occurs when they compare what happened; conceptualization begins when they formulate a simple causal explanation; and active experimentation occurs when they test the explanation in a subsequent activity.

Experiment-based inquiry has been shown to strengthen children's understanding of simple science concepts, problem-solving, and cause-and-effect relationships by enabling them to learn through direct manipulation and evidence-based observation (Bargiela et al., 2022; Speldewinde, 2024; Yulinda et al., 2026). Similarly, STEAM activities that use direct experience and play-based projects provide opportunities for young children to analyze problems, test ideas, and construct solutions (Aryani et al., 2024; Hapidin et al., 2020; Kastriti et al., 2022). Therefore, the great improvement in causal reasoning in this study was likely produced by the alignment between children's developmental need for concrete experience and SEMAI's systematic use of observable natural phenomena.

The second-largest improvement, drawing conclusions from observations or experiments, is specifically associated with the connection among the Envision, Apply, and Iterate stages. During Envision, children are guided to formulate questions and simple predictions. During Apply, they collect experiential evidence through observation and experimentation. During Iterate, they compare the results with their initial predictions, communicate their observations, and formulate simple conclusions. This sequence gives children a clear cognitive pathway from anticipation to evidence and from evidence to conclusion.

The conclusion-drawing process is particularly important because hands-on activity alone does not automatically produce critical thinking. Children may participate enthusiastically in experiments without understanding the relationship between the activity and its result. The Iteration stage prevents the project from ending when the physical activity is completed. It requires children and teachers to revisit the initial question, compare different outcomes, discuss discrepancies, and express what has been learned. This process reflects the concluding phase of Katz and Chard's Project Approach (Beneke et al., 2019; Helm et al., 2023; Owen, 2007) and the transition from reflective observation to conceptualization in experiential learning theory (Healey & Jenkins, 2000; Kolb & Kolb, 2005; Passarelli & Kolb, 2023).

The explicit reflective function of Iterate is therefore one of the main mechanisms that distinguish SEMAI from project activities primarily focused on producing an object or completing a task. The model directs children's attention toward the meaning of the result rather than merely the result itself. Previous JPUD research has similarly shown that project learning can enable children to present project outcomes and describe the processes by which those outcomes are produced when teachers understand the stages of the project and provide appropriate facilitation (Hapidin et al., 2023). The integration of project work, reflection, and evidence-based discussion in SEMAI may consequently explain why the ability to draw conclusions improved more strongly than several other indicators.

The improvements in giving reasons for opinions and selecting the best solution, both of which increased by 1.53 points, show that SEMAI also supported evaluative and decision-making processes. These skills were exercised when children were asked to explain a prediction, select materials, compare alternative actions, or decide how to respond to a problem encountered during a project. The Envision stage created opportunities to anticipate possible outcomes, while the Apply stage allowed children to evaluate their ideas against observable evidence. When an initial idea did not produce the expected outcome, children were encouraged to modify the plan rather than merely being told the correct answer.

These findings are consistent with research showing that problem- and project-based learning can promote higher-order thinking by engaging children in observing phenomena, identifying problems, developing solutions, and drawing conclusions (Alisia et al., 2025). Project-based learning has also been found to improve problem-solving performance because children become actively involved in authentic and meaningful situations rather than receiving predetermined solutions from teachers (Cahyani et al., 2024; Pranoto, 2025; Putri et al., 2023). However, SEMAI extends these approaches by embedding problem solving within a strategic instructional cycle. Problems are not introduced randomly; they are selected during Prepare, formulated during Envision, supported through resource organization during Mobilize, investigated during Apply, and evaluated during Iterate.

The development of reasoning and solution selection was also mediated through social interaction. Vygotsky's, sociocultural theory proposes that children's higher mental functions develop through language, interaction, and guided participation (Vygotsky, 2018; Yousef & Mahameed, 2022; Zavershneva & van der Veer, 2021). In SEMAI activities, teachers used prompts and open-ended questions to help children explain observations, compare possible answers, and justify choices. Group activities also allowed children to hear alternative explanations and reconsider their own ideas. Teacher scaffolding operated within the child's zone of proximal development by providing enough assistance to extend reasoning without replacing the child's thinking.

From this perspective, communication and collaboration are not only additional social outcomes of SEMAI; they are mechanisms through which critical thinking develops. When children explain an idea, respond to a peer, or negotiate the use of materials, their implicit thinking becomes explicit and open to reconsideration. Project and STEAM learning have similarly emphasized that collaborative activities, discussion, direct experience, and integrated play can develop problem-solving, curiosity, communication, and critical thinking simultaneously (Hasibuan et al., 2022; Pujianti et al., 2023; Syukri et al., 2022). The moderate improvement in active participation in group discussions therefore supports the view that early critical thinking is socially constructed rather than developed solely through individual cognitive activity.

Nevertheless, questioning the accuracy of information showed the smallest gain among the indicators. This result requires critical consideration. Evaluating whether information is accurate is cognitively more demanding than recognizing a visible causal relationship. It requires children to distinguish a statement from its supporting evidence, compare more than one source or explanation, and understand that information provided by another person may need to be examined. These processes involve early epistemic cognition and metacognitive control, which are still developing at five to six years of age.

The relatively smaller increase in explaining thought processes to others may have a similar explanation. A child may recognize that watering affects plant growth but still find it difficult to describe

the sequence of observations and reasoning in organized language. The ability to communicate a thought process requires conceptual understanding, vocabulary, memory, sequencing, and perspective-taking. Consequently, a short intervention may produce faster gains in observable reasoning than in the ability to verbalize the reasoning process.

These findings do not indicate that SEMAI was ineffective for evaluative or communicative thinking. Instead, they suggest that such indicators may require more intensive and repeated scaffolding. Teachers could strengthen these abilities by presenting contrasting explanations, introducing unexpected results, and repeatedly asking questions such as "How do you know?", "What evidence did you see?", "Is there another possibility?", and "Why is your answer different from your friend's?" Traditional and play-based activities can stimulate HOTS when they are deliberately managed and include opportunities for children to think and act scientifically and systematically (Aryani et al., 2024; Hasni et al., 2024; Pendidikan et al., 2024). Thus, future SEMAI implementation should provide more structured opportunities for children to challenge information, reconsider initial beliefs, and explain the evidence underlying their conclusions.

The effectiveness of SEMAI can also be interpreted through the function of its five interrelated stages. Preparation enables teachers to identify children's prior experiences, developmental needs, environmental resources, safety considerations, and suitable phenomena. This stage enhances the project's relevance and prevents teachers from selecting activities that are attractive yet cognitively disconnected from the intended indicators. Envision transforms curiosity into a line of inquiry by encouraging children to formulate questions and predictions. Mobilize ensures that materials, time, roles, groups, and safety procedures are organized before the investigation begins. Apply provides direct opportunities for observation, experimentation, comparison, and problem solving. Iterate links the experience back to the original question through reflection, conclusion, feedback, and improvement.

Mobilize may appear less directly related to critical thinking than Apply or Iterate, but it serves an important enabling function. Well-organized materials, roles, and safety procedures reduce unnecessary disruptions and allow children to focus on the phenomenon being investigated. Group organization also ensures that children have meaningful opportunities to observe, manipulate materials, discuss, and communicate. Thus, the improvement in critical thinking cannot be attributed solely to experimentation; it is also supported by the instructional conditions established prior to the experiment.

The integration of these stages reflects Wheelen and Hunger's, strategic management cycle, particularly the stages of environmental scanning, formulation, implementation, evaluation, and control (Machmud, 2024; Wei-Hin Cheng et al., 2014; Wheelen & Hunger, 2012). When adapted to classroom learning, the cycle helps teachers align learning objectives, resources, instructional actions, and assessment. The critical contribution of strategic management in SEMAI is, therefore, instructional coherence. Each activity is connected to a predetermined critical-thinking objective, and evidence from one cycle serves as input to improve the next cycle. This iterative process is consistent with the view that sustainable learning requires planning, monitoring, reflection, and refinement rather than a succession of disconnected activities.

The natural environment also played an important role, but the findings suggest that access to nature alone is insufficient. The needs analysis showed that both institutions already had outdoor areas and natural resources before the intervention, yet children's initial reasoning remained largely dependent on teacher direction. The improvement after SEMAI indicates that natural settings become cognitively productive when teachers intentionally transform them into structured contexts for inquiry. Nature offers diverse and changing materials that invite children to observe, compare, classify, predict, and test ideas. Plants, water, soil, wind, light, and small animals provide immediate sensory feedback and allow multiple observations over time. Research has shown that nature-based early childhood education can support cognitive, social, and emotional development through direct and meaningful engagement with the environment. Environmental education studies in JPUD also indicate that gardening, exploration of plants and animals, creative environmental games, and school greening activities can provide meaningful contexts for early learning (Chandrawati & Aisyah, 2022; Priadi & Fatria, 2024). SEMAI builds on this potential by converting natural encounters into a sequence of inquiry and reflection.

Another important mechanism is the repositioning of teachers from activity providers to strategic facilitators. Teachers in SEMAI identify appropriate phenomena, prepare resources, formulate prompts, observe children's responses, and use assessment data to guide subsequent activities. This role is more complex than simply demonstrating an experiment or supervising outdoor play. The teacher must decide when to provide assistance, when to ask a question, and when to allow children to investigate independently. This interpretation is supported by studies showing that teachers' understanding of project syntax and

integrated STEAM content determines whether project learning becomes directed, concrete, and cognitively meaningful. Therefore, part of the SEMAI effect may have resulted from greater pedagogical intentionality. Because the observation rubric specified critical-thinking indicators, teachers could focus on processes such as questioning, reasoning, use of evidence, decision-making, and reflection rather than evaluating only the final project product.

The similar large effect size at State Kindergarten 1 Bekasi and BBIS Bekasi suggests that SEMAI was adaptable across the two institutional settings included in the study. The institutions differed in management characteristics, curriculum culture, and initial score distributions, but both demonstrated substantial improvement. This consistency suggests that the model's central mechanisms, structured inquiry, concrete experience, scaffolding, collaboration, and reflection can operate across multiple early childhood education contexts.

However, this finding should not be interpreted as definitive evidence of broad external validity. Both institutions were purposively selected, located in the same city, and demonstrated readiness to implement the intervention. In addition, the relatively high and homogeneous BBIS posttest scores may indicate a possible ceiling effect. When children's scores approach the maximum instrument score, the rubric may become less sensitive to differences among children with stronger performance. Future research should therefore examine SEMAI in institutions with more varied resources, teacher profiles, geographic conditions, and child populations.

The findings also clarify SEMAI's novelty relative to conventional PjBL. Existing project-based learning research demonstrates that projects can promote engagement, problem-solving, communication, and higher-order thinking. Nevertheless, PjBL may become product-oriented when the relationship among project objectives, teacher facilitation, assessment indicators, and reflection is not clearly structured. SEMAI addresses this limitation by linking each stage to a management function and observable critical-thinking indicators. The project is therefore not the final objective; it is the medium through which children question, investigate, evaluate, conclude, communicate, and revise understanding.

In practice, the results imply that effective SEMAI projects should meet several essential conditions. Teachers should select natural phenomena with observable differences or changes, ask children to make predictions before the activity, provide opportunities to compare conditions, document children's observations, and allocate sufficient time for reflection. The Iterate stage should not be reduced to asking whether children enjoyed the project. It should encourage children to compare predictions with results, identify evidence, explain discrepancies, and suggest improvements for the next investigation.

Additional emphasis should be given to indicators that demonstrated relatively smaller gains. Teachers can introduce multiple explanations for the same phenomenon, intentionally create prediction–outcome discrepancies, and facilitate respectful peer disagreement. Repeated project cycles may enable children to move from stating what happened toward explaining how they know and evaluating whether an explanation is supported by evidence.

Finally, the findings must be interpreted in light of the study design. The one-group pretest-posttest design does not fully rule out alternative explanations, such as maturation, repeated testing, observer expectations, or experiences outside the intervention. Because classroom teachers also participated in facilitation and observation, expectancy effects may have influenced scoring despite rubric preparation. The two-week intervention also provides limited evidence about the durability and transfer of the observed gains.

Future studies should employ quasi-experimental or randomized designs with comparison groups, independent or blinded observers, explicit inter-rater reliability analysis, and follow-up measurements. Research should also examine implementation fidelity and calculate indicator-level effect sizes to determine which SEMAI components contribute most strongly to particular critical thinking dimensions. Qualitative analysis of children's questions, explanations, peer discussions, and revisions of ideas would further clarify the cognitive and social mechanisms through which SEMAI operates.

Overall, the findings suggest that SEMAI supports early childhood critical thinking not simply because children participate in enjoyable nature projects, but because the model organizes those experiences into a coherent cycle of preparation, questioning, resource mobilization, evidence generation, social reasoning, reflection, and improvement. Its strongest influence on cause-and-effect reasoning and conclusion drawing reflects the alignment between concrete natural phenomena and the Apply–Iterate sequence. Its more moderate influence on epistemic questioning and verbalized thought processes indicates areas that require longer-term, more deliberately scaffolded intervention. This interpretation positions

SEMAI as a structured instructional-management model that transforms nature-based projects from isolated activities into sustained opportunities for evidence-based, reflective, and collaborative thinking.

5. Conclusion

This study concludes that the SEMAI Nature-Based Project Model is effective in enhancing early childhood critical thinking skills. Significant improvements were observed in both participating institutions, with large effect sizes and higher posttest scores across all 12 indicators. The greatest gains occurred in identifying simple cause-and-effect relationships and drawing conclusions from observations or experiments. These findings indicate that critical thinking develops more effectively when children engage directly with natural phenomena through questioning, prediction, experimentation, discussion, and reflection. The theoretical contribution of this study lies in integrating Project-Based Learning, nature-based learning, experiential learning, social constructivism, and strategic management into a single instructional framework. The five SEMAI stages, Prepare, Envision, Mobilize, Apply, and Iterate, extend conventional project learning by organizing activities into a systematic and cyclical process of planning, implementation, assessment, reflection, and improvement. The findings also demonstrate that natural environments become meaningful contexts for critical thinking when teachers intentionally structure children's experiences as inquiry-based learning. Practically, SEMAI provides early childhood educators with a clear framework for designing purposeful and developmentally appropriate nature-based projects. Teachers should identify children's prior knowledge and available environmental resources, formulate critical thinking objectives, organize materials and safety procedures, and provide opportunities for direct observation and simple experimentation. Open-ended questions such as "What will happen?", "Why did it change?", and "How do you know?" can encourage children to explain evidence, evaluate alternatives, and justify their conclusions. Critical thinking should be assessed through structured observation, field notes, children's work, and learning portfolios rather than only through final project products. Greater attention is needed for skills that showed relatively smaller gains, particularly questioning the accuracy of information and explaining thought processes. These abilities require repeated scaffolding, language support, and longer learning cycles. Schools should therefore support teachers through collaborative planning, professional development, and access to safe natural learning environments. The findings should be interpreted cautiously because the study used a one-group pretest-posttest design, involved only two purposively selected institutions, and was conducted over a relatively short period. Future research should include comparison groups, independent observers, longer interventions, and follow-up assessments. Overall, SEMAI offers a theoretically grounded and practically applicable model for transforming nature-based projects into systematic opportunities for inquiry, reasoning, communication, and reflection in early childhood education.

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7. References

Agarwal, R., & Selen, W. (2009). Dynamic Capability Building in Service Value Networks for Achieving Service Innovation. *Decision Sciences*, *40*(3), 431–475. https://doi.org/10.1111/j.1540-5915.2009.00236.x

Alisia, N., Martuty, A., Syamsuardi, S., Bahri, A., Intisari, I., Amri, N. A., & Hasbur, H. S. (2025). The Effect of the Application of the Problem Based Learning (PBL) Learning Model on Early Childhood High Order Thinking Skill (HOTS): A Quasi-Experimental Study. *JPUD-Jurnal Pendidikan Usia Dini*, *19*(2), 295–306.

Almulla, M. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. *Sage Open*, *10*(3). https://doi.org/10.1177/2158244020938702

Alnoukari, M. (2021). A framework for big data integration within the strategic management process based on a balanced scorecard methodology. *Journal of Intelligence Studies in Business*, *11*(1), 33–47.

Arndt, S., Urban, M., Murray, C., Smith, K., Swadener, B., & Ellegaard, T. (2018). Contesting early childhood professional identities: A cross-national discussion. *Contemporary Issues in Early Childhood*, *19*(2), 97–116.

Aryani, N., Rizka, N., Suparmi, S., Artamevia, F., & Nazli, N. L. M. (2024). Higher Order Thinking Skill (HOTS) through STEAM learning for early childhood. *JPUD-Jurnal Pendidikan Usia Dini*, *18*(2),

308–314.
Bargiela, I. M., Anaya, P. B., & Puig, B. (2022). Questions for Inquiry and the Activation of Critical Thinking in Early Childhood Education. *Ensenanza de Las Ciencias*, *40*(3), 11–28. https://doi.org/10.5565/rev/ensciencias.5470
Bassok, D., Latham, S., & Rorem, A. (2016). Is Kindergarten the New First Grade? *Aera Open*, *2*(1). https://doi.org/10.1177/2332858415616358
Ben-Eliyahu, A. (2021). Sustainable learning in education. *Sustainability*, *13*(8), 4250.
Beneke, S., Ostrosky, M. M., & Katz, L. G. (2019). *The Project Approach for All Learners: A Hands-On Guide for Inclusive Early Childhood Classrooms*. ERIC.
Cahyani, V. P., Romadin, A., Erniyani, Anwar, F., & Nawi, M. Z. M. (2024). Optimising Assessment in Project-Based Learning to Improve the Quality of STEM Learning. *International Journal of Scientific Multidisciplinary Research*, *2*(11), 1645–1656. https://doi.org/10.55927/ijsmr.v2i11.12392
Chandrawati, T., & Aisyah, S. (2022). ECE Educator Training: How to Develop Literacy and Environment Education for Children? *Jpud - Jurnal Pendidikan Usia Dini*, *16*(1), 133–148. https://doi.org/10.21009/jpud.161.09
Cheng, W.-H., Kadir, K. A., & Bohari, A. M. (2014). The Strategic Planning Of Smes In Malaysia: A View Of External Environmental Scanning. *International Journal of Business & Society*, *15*(3).
Cronin de Chavez, A., Seims, A. L., Dickerson, J., Dharni, N., & McEachan, R. R. C. (2024). Unlocking the forest: An ethnographic evaluation of Forest Schools on developmental outcomes for 3-year-olds unaccustomed to woodland spaces. *Wellcome Open Research*, *9*, 1–22. https://doi.org/10.12688/wellcomeopenres.22851.1
Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140.
Dewey, J. (2022). *How we think*. DigiCat.
Feriver, Ş., Olgan, R., Teksöz, G., & Barth, M. (2019). Systems Thinking Skills of Preschool Children in Early Childhood Education Contexts From Turkey and Germany. *Sustainability*, *11*(5), 1478. https://doi.org/10.3390/su11051478
Gemmell, R. M., & Kolb, D. A. (2020). Experiential learning and creativity in entrepreneurship. *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship*, 937–944.
Gunarti, W., Pujianti, Y., & Syarah, E. S. (2020). STEAM to R-SLAMET modification: An integrative thematic play based learning with R-SLAMETS content in early child-hood education. *Jurnal Pendidikan Usia Dini*, *14*(2), 262–274.
Hapidin, H., Gunarti, W., Pujianti, Y., & Suharti, S. (2023). Penerapan Model Pembelajaran Proyek Bermuatan Konten STEAM melalui Media Komik dalam Implementasi Kurikulum Merdeka di Satuan PAUD. *Jurnal Abdimas Prakasa Dakara*, *3*(2), 126–133.
Hapidin, Pujianti, Y., Hartati, S., Nurani, Y., & Dhieni, N. (2020). The continuous professional development for early childhood teachers through lesson study in implementing play based curriculum (case study in Jakarta, Indonesia). *International Journal of Innovation, Creativity and Change*, *12*(10).
Harris, T., & Hardin, J. W. (2013). Exact Wilcoxon signed-rank and Wilcoxon Mann–Whitney ranksum tests. *The Stata Journal*, *13*(2), 337–343.
Hasibuan, R., Fitri, R., & Dewi, U. (2022). STEAM-Based Learning Media: Assisting in Developing Children's Skills. *Jurnal Obsesi Jurnal Pendidikan Anak Usia Dini*, *6*(6), 6863–6876. https://doi.org/10.31004/obsesi.v6i6.3560
Hasni, U., Amanda, R. S., & Pangaribuan, T. (2024). *Need Analysis: Development of the Learning Cycle 5E Model to Improve HOTS in Early Childhood Student*. 192–197. https://doi.org/10.2991/978-2-38476-206-4_22
Healey, M., & Jenkins, A. (2000). Kolb's experiential learning theory and its application in geography in higher education. *Journal of Geography*, *99*(5), 185–195.
Helm, J. H., Katz, L. G., & Wilson, R. (2023). *Young investigators: The project approach in the early years*. Teachers College Press.
Herodotou, C. (2017). Young Children and Tablets: A Systematic Review of Effects on Learning and Development. *Journal of Computer Assisted Learning*, *34*(1), 1–9. https://doi.org/10.1111/jcal.12220
Johnstone, A., McCrorie, P., Cordovil, R., Fjørtoft, I., Iivonen, S., Jidovtseff, B., Lopes, F., Reilly, J. J., Thomson, H., Wells, V., & Martin, A. (2022). Nature-Based Early Childhood Education and

Children's Physical Activity, Sedentary Behavior, Motor Competence, and Other Physical Health Outcomes: A Mixed-Methods Systematic Review. *Journal of Physical Activity and Health*, *19*(6), 456–472. https://doi.org/10.1123/jpah.2021-0760

Kastriti, E., Kalogiannakis, M., Psycharis, S., & Vavougios, G. D. (2022). The Teaching of Natural Sciences in Kindergarten Based on the Principles of STEM and STEAM Approach. *Advances in Mobile Learning Educational Research*, *2*(1), 268–277. https://doi.org/10.25082/amler.2022.01.011

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education*, *4*(2), 193–212.

Kuo, M., Dettweiler, U., Faber Taylor, A., Jordan, C., & Wells, N. M. (2023). Nature-based learning and development: maximizing the returns on investment, volume II. In *Frontiers in Psychology* (Vol. 14, p. 1304644). Frontiers Media SA.

Machmud, P. (2024). Pengembangan Model Manajemen Stratejik (Wheelen and Hunger). *JIMAD: Jurnal Ilmiah Multidisiplin*, *1*(3), 134–144.

Marchant, E., Todd, C., Cooksey, R., Dredge, S., Jones, H., Reynolds, D., Stratton, G., Dwyer, R., Lyons, R. A., & Brophy, S. (2019). Curriculum-Based Outdoor Learning for Children Aged 9-11: A Qualitative Analysis of Pupils' and Teachers' Views. *Plos One*, *14*(5), e0212242. https://doi.org/10.1371/journal.pone.0212242

Markowitz, A. J., Bassok, D., & Player, D. (2020). Simplifying quality rating systems in early childhood education. *Children and Youth Services Review*, *112*(October 2019), 104947. https://doi.org/10.1016/j.childyouth.2020.104947

Mathooko, F. M., & Ogutu, M. (2015). Porter's five competitive forces framework and other factors that influence the choice of response strategies adopted by public universities in Kenya. *International Journal of Educational Management*, *29*(3), 334–354.

Owen, P. M. (2007). Integrating Katz and Chard's project approach with multicultural education in the university classroom. *Journal of Early Childhood Teacher Education*, *28*(3), 219–232.

Passarelli, A. M., & Kolb, D. A. (2023). Experiential Learning Theory. *Student Learning Abroad: What Our Students Are Learning. What They're Not, and What We Can Do About It*.

Pendidikan, J. I., Fongkanta, P., & Buakanok, F. S. (2024). *Cakrawala Pendidikan Development novice teachers ' higher -order thinking skills through online problem-based learning platform : A mixed methods experimental research*. *43*(3), 756–764.

Pholphirul, P. (2016). Pre-Primary Education and Long-Term Education Performance: Evidence From Programme for International Student Assessment (PISA) Thailand. *Journal of Early Childhood Research*, *15*(4), 410–432. https://doi.org/10.1177/1476718x15616834

Pranoto, Y. K. S. (2025). The Effect of Project-Based Learning Model on Problem Solving Skills in Coastal PAUD Institutions. *JPUD-Jurnal Pendidikan Usia Dini*, *19*(1), 28–36.

Priadi, A., & Fatria, E. (2024). The development of early childhood naturalist intelligence through environmental education. *JPUD-Jurnal Pendidikan Usia Dini*, *18*(1), 30–52.

Pujianti, Y., Aminah, S., Nuryati, E., Mulyanto, A., & Sariff, A. F. (2025). A Systematic Literature Review of Internal Quality Assurance in Early Childhood Education in Developed and Developing Countries: Internal Quality Assurance in Early Childhood Education. *Indonesian Journal of Educational Research and Review*, *8*(1), 273–291.

Pujianti, Y., Syarah, E. S., & Gunarti, W. (2023). Teacher's Understanding of Project Learning Models through Children's Comics with STEAM Content in Indonesia. *Jurnal Pendidikan Usia Dini*, *17*(1), 82–97.

Putri, A. A. P., Rahardjo, B., & Olby, N. A. (2023). Project-Based Learning Model Improves Ability to Understand Environmental Cleanliness in Early Childhood. *Jurnal Pendidikan Anak Usia Dini Undiksha*, *11*(1), 43–51. https://doi.org/10.23887/paud.v11i1.54589

Quay, J. (2019). John Dewey's conceptualisation of experience. In *Experiential Learning and Outdoor Education* (pp. 71–90). Routledge.

Rohita, R., Firmiana, M. E., & Arianti, G. (2025). Development of a Digital Storybook Based on Lebak Culture to Foster Critical Thinking Skills in Early Childhood. *JPUD-Jurnal Pendidikan Usia Dini*, *19*(2), 197–206.

Schachter, R. E., Spear, C. F., Piasta, S. B., Justice, L. M., & Logan, J. A. R. (2016). Early Childhood Educators' Knowledge, Beliefs, Education, Experiences, and Children's Language- And Literacy-

Learning Opportunities: What Is the Connection? *Early Childhood Research Quarterly*, *36*, 281–294. https://doi.org/10.1016/j.ecresq.2016.01.008

Shieh, G., Jan, S.-L., & Randles, R. H. (2007). Power and sample size determinations for the Wilcoxon signed-rank test. *Journal of Statistical Computation and Simulation*, *77*(8), 717–724.

Speldewinde, C. (2024). Dipping your toes in the water: early childhood science learning at a beach kindergarten. *Journal of Outdoor and Environmental Education*. https://doi.org/10.1007/s42322-024-00178-0

Speldewinde, C., & Campbell, C. (2024). Bush kinders: Building young children's relationships with the environment. *Australian Journal of Environmental Education*, *40*(1), 7–21. https://doi.org/10.1017/aee.2023.36

Syarah, E. S., Pujianti, Y., & Gunarti, W. (2022). Instilling Children's Ocean Literacy Through Comic Media: STEAM to R-SLAMET Learning Design for ECE educators. *Jurnal Pendidikan Usia Dini*, *16*(1), 1–16.

Syukri, M., Ukhaira, Z., Zainuddin, Z., Herliana, F., & Arsad, N. M. (2022). The Influence of STEAM-Based Learning Application on Students' Critical Thinking Ability. *Asian Journal of Science Education*, *4*(2), 37–45. https://doi.org/10.24815/ajse.v4i2.28272

Thomassen, A. O., & Jørgensen, K. M. (2021). John Dewey and continuing management education: problem-based learning for organizational sustainability. *Journal of Workplace Learning*, *33*(3), 229–242.

Traynor, O., Martin, A., Johnstone, A., Chng, N. R., Kenny, J., & McCrorie, P. (2022). A low-cost method for understanding how nature-based early learning and childcare impacts children's health and wellbeing. *Frontiers in Psychology*, *13*, 889828.

Trina, N. A., Monsur, M., Cosco, N., Shine, S., Loon, L., & Mastergeorge, A. (2024). How Do Nature-Based Outdoor Learning Environments Affect Preschoolers' STEAM Concept Formation? A Scoping Review. *Education Sciences*, *14*(6), 627. https://doi.org/10.3390/educsci14060627

Vygotsky, L. (2018). Lev Vygotsky. *La Psicología En La Revolución Rusa. Colombia: Ediciones Desde Abajo*.

Wei-Hin Cheng, Kadzrina Abdul Kadir, & Abdul Manaf Bohari. (2014). The strategic planning of SMES in Malaysia: a view of external environmental scanning. *International Journal of Business and Society*, *15*(3), 437–446.

Wheelen, T. L., & Hunger, J. D. (2012). Strategic management and business policy: concepts and cases. *(No Title)*.

Yelland, N. (2018). A Pedagogy of Multiliteracies: Young Children and Multimodal Learning With Tablets. *British Journal of Educational Technology*, *49*(5), 847–858. https://doi.org/10.1111/bjet.12635

Yousef, N. T., & Mahameed, M. I. (2022). Reading Yeats's 'A Prayer for My Daughter'in Light of Lev Vygotsky's Sociocultural Theory of Learning. *Theory and Practice in Language Studies*, *12*(2), 241–247.

Yuliantina, I. (2025). Development of Learning Strategies to Integrate Computational Thinking in Early Childhood Education Curriculum: A Study on 36 Early Childhood Education Units in Kudus. *JPUD-Jurnal Pendidikan Usia Dini*, *19*(1), 37–47.

Yulinda, Y., Syamsuardi, S., Akib, T., Intisari, I., Amri, N. A., & Hasbur, H. S. (2026). The Effect of Experiment-Based Inquiry Method on the Science Ability of Children Aged 5-6 Years at Aisyiyah Bustanul Athfal III Paranga Kindergarten, Gowa Regency: A Quasi-Experimental Study. *JPUD-Jurnal Pendidikan Usia Dini*, *20*(1), 74–85.

Zavershneva, E., & van der Veer, R. (2021). Lev Vygotsky. In *Encyclopedia of evolutionary psychological science* (pp. 4539–4542). Springer.

Zucca, C., McCrorie, P., Johnstone, A., Chambers, S., Chng, N. R., Traynor, O., & Martin, A. (2023). Outdoor nature-based play in early learning and childcare centres: Identifying the determinants of implementation using causal loop diagrams and social network analysis. *Health & Place*, *79*, 102955.