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Models and Techniques of Science Learning in Cultivating Cognitive and Socio-Emotional Learning Attitudes in Early Childhood in Banten Province, Indonesia

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Research Article

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Abstract

Background/purpose. Early Childhood Education (ECE) is critical in shaping cognitive and socio-emotional development. In Banten Province, Indonesia, most ECE institutions are privately operated, reflecting strong community involvement. This study examined the coherence between learning models and techniques in fostering scientific attitudes, cognitive learning, and socio-emotional learning among young children.

Materials/methods. A quantitative ex post facto design was applied using Structural Equation Modelling (SEM) to analyse relationships among variables. Data were collected from 199 ECE institutions selected through proportionate stratified random sampling (99 formal and 100 non-formal). The study investigated four learning models: group-based, corner-based, area-based, and centre-based, and two techniques: exploration-based and direct experience-based.

Results. The findings reveal that group-based and centre-based learning models play a significant role in fostering scientific attitudes and interest in science learning. Cognitive learning attitudes are best supported when group-based and centre-based models are combined with exploration-based techniques, while socio-emotional learning attitudes are more effectively developed when the group-based model is paired with direct experience techniques. Other models, such as corner-based and area-based learning, demonstrated limited coherence with enhancing learning attitudes.

Conclusion. The study highlights the importance of aligning learning models with appropriate techniques to optimize early childhood education outcomes. Integrating group-based and centre-based models with exploration or direct experience techniques significantly improves attitudes toward cognitive and socio-emotional learning. These findings provide valuable implications for developing pedagogical strategies that strengthen scientific interest and holistic development in early learners.

1. Introduction

Early Childhood Education (ECE) is increasingly recognized worldwide as the foundation for lifelong learning and development. Scholars and policymakers agree that the first years of life represent a critical period for cognitive, socio-emotional, and behavioural development, laying the foundation for later success in school and society (Ardoin & Heimlich, 2021). Through structured learning opportunities, children acquire not only academic readiness but also essential skills such as curiosity, problem-solving, and collaboration. In this regard, the design of effective ECE practices is central to educational research and policy debates worldwide.

In Indonesia, ECE comprises both formal and non-formal tracks, with institutions classified as either public or private. As of 2024, there are 136,318 formal ECE institutions and 108,531 non-formal ones nationwide (Kalsum et al., 2023). Of the formal institutions, only 7,275 are public while 129,043 are private. In the non-formal sector, only 337 institutions are public compared to 108,194 that are privately operated. In Banten Province, one of Indonesia's rapidly developing regions, there are 4,159 formal and 4,240 non-formal ECE institutions. Among the formal institutions, 116 are public and 4,043 are private, whereas all non-formal institutions are privately managed. The dominance of private institutions highlights the active role of communities in ensuring access to early education. Importantly, these institutions pursue a broad developmental agenda that includes religious and moral development, physical and motor skills, cognitive growth, language acquisition, socio-emotional development, and the arts (Rahmawati & Suryaalamsyah, 2022). This multidimensional mandate reflects Law No. 20 of 2023 on the National Education System, which emphasizes holistic and optimal child development.

One important indicator of development in ECE is children's learning attitudes. Learning attitude refers to an individual's tendency to respond positively or negatively to learning situations, expressed through feelings of enjoyment, curiosity, interest, or cooperation. In early childhood, these attitudes manifest in distinct behaviours: the enjoyment of speaking, eagerness to observe, persistence in solving problems, and willingness to cooperate with peers (Jacobsen et al., 2025). Learning attitudes encompass several dimensions, including acceptance, responsiveness, appreciation, and responsibility. Scholars argue that cognitive learning attitudes can be stimulated through exploration and inquiry, while socio-emotional learning attitudes develop through interaction and collaboration (Maharani et al., 2023).

Cognitive learning attitudes involve complex processes of memory, comprehension, analysis, and creative thinking. They allow children to actively process and apply information, laying the groundwork for academic skills and critical thinking. Socio-emotional learning attitudes, on the other hand, involve empathy, cooperation, and communication. These qualities enable children to regulate emotions, build relationships, and adapt to diverse social situations. Both dimensions are essential for preparing children to thrive in the 21st century, where adaptability, problem-solving, and interpersonal skills are as important as knowledge acquisition.

Science learning has been identified as one of the most effective domains for fostering both cognitive and socio-emotional learning attitudes. Science learning refers to structured activities that encourage discovery, fact-finding, inquiry, and discussion, helping children to make sense of their environment through observation and experimentation (Adnyani, 2021). At the early childhood level, science learning aims to nurture curiosity, honesty, persistence, and critical thinking while fostering problem-solving skills. Furthermore, it fosters an intrinsic interest in science, an important foundation for later STEM learning. The dual focus on knowledge and attitudes makes science education particularly suitable for holistic child development.

To achieve these outcomes, the application of appropriate learning models and techniques is crucial. Among the models used in Indonesian ECE are the group-based, area-based, corner-based,

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and centre-based approaches. In group-based learning, children are divided into small groups to complete activities together, encouraging collaboration, imagination, and the sharing of responsibilities (Lubis & Ariqah, 2025). Area-based learning provides freedom of choice, enabling children to select activities aligned with their interests and thereby enhancing logical and symbolic thinking (Putri, 2023). The corner-based model offers more structured yet varied activity corners, promoting creativity and real-life problem-solving. The centre-based model emphasizes scaffolding and structured play environments, supporting rule formation, decision-making, and knowledge-building.

Complementing these models are learning techniques that prioritize active participation. The exploration-based technique engages children directly with their environment, encouraging them to observe, investigate, imitate, and imagine. The direct experience-based technique, meanwhile, allows children to participate in real-life activities, providing hands-on learning that strengthens socio-emotional bonds (Parker et al., 2022). The alignment of models and techniques is critical: while models provide the structural framework for learning, techniques operationalize children's engagement within that framework.

1.1. Research gap

Despite recognition of the importance of models and techniques in ECE, much of the existing literature has examined them in isolation. Studies have shown that group-based learning enhances social interaction and problem-solving (Suharni et al., 2020), while exploration-based learning stimulates curiosity and cognitive growth (Wijaya & Dewi, 2021). However, few empirical studies have systematically analysed the coherence between models and techniques in shaping both cognitive and socio-emotional learning attitudes. In particular, evidence from Indonesia remains limited, despite the country's unique context of community-driven ECE institutions. As a result, practitioners lack clear guidance on which combinations of models and techniques best foster scientific attitudes and holistic development in young learners.

1.2. Significance of the study

Addressing this gap is important for several reasons. First, by identifying effective combinations of learning models and techniques, the study provides actionable insights for teachers and curriculum developers in Indonesian ECE. Second, it contributes to the international literature on early science education by offering empirical evidence from a non-Western context. Third, the study supports policy goals outlined in Indonesia's national education framework, which call for integrated approaches to children's cognitive and socio-emotional growth. Finally, the findings can inform teacher training and resource allocation, ensuring that pedagogical strategies align with developmental needs.

1.3. Purpose of the study

This study aims to evaluate the coherence between learning models and techniques in cultivating cognitive and socio-emotional learning attitudes among early childhood learners in Banten Province. The focus is on how different models (group-based, corner-based, area-based, and center-based) and techniques (exploration-based and direct experience-based) interact to foster scientific attitudes and interest in science learning.

1.4. Research questions

1 Which learning models significantly foster scientific attitudes and interest in science learning among early childhood learners?

2 How do exploration-based and direct experience-based techniques contribute to cognitive and socio-emotional learning attitudes?

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3 What combinations of learning models and techniques are most effective in enhancing early learners' cognitive and socio-emotional development?

2. Literature Review

2.1. Early Childhood Education and Learning Attitudes

Early Childhood Education (ECE) is widely acknowledged as a crucial foundation for lifelong learning and holistic child development (Ulfadhilah, 2021). International research consistently demonstrates that participation in high-quality ECE programs improves later academic achievement, socio-emotional adjustment, and life skills, while also reducing educational inequality. These benefits extend beyond immediate learning gains to long-term social and economic advantages, such as higher school completion rates and stronger workforce participation.

In Indonesia, ECE has expanded rapidly, supported by government initiatives and strong community engagement (Rahayu, 2021). However, the majority of institutions, especially in Banten Province, remain privately managed, resulting in considerable variation in learning practices and resource availability. While the policy framework emphasizes holistic growth spanning cognitive, linguistic, socio-emotional, moral, and physical domains, the extent to which institutions implement balanced pedagogical approaches remains uneven. This creates an urgent need to identify strategies that not only enhance knowledge acquisition but also nurture positive learning attitudes that reflect curiosity, resilience, and social adaptability.

2.2. Cognitive Learning in Early Childhood

Cognitive learning attitudes in early childhood encompass abilities such as memory, comprehension, analysis, and creativity (Revenko et al., 2024). These attitudes enable children to actively process information, engage in reasoning, and apply knowledge in new contexts. Inquiry-based and exploratory activities are widely recognized as particularly effective for stimulating cognitive engagement. Found that structured exploration and guided discovery activities strengthen children's problem-solving capacity and critical thinking skills (Kurnia et al., 2024). Similarly, international studies show that early exposure to inquiry-based science fosters not only knowledge but also transferable skills, including logical reasoning and innovative thinking.

Despite this, much of the research on cognitive development in Indonesia and similar contexts focuses on primary school-aged children rather than preschoolers (Haryono, 2020; Suebsing, 2024). As a result, less is known about how younger children develop cognitive learning attitudes through structured science learning experiences. This gap is significant because early intervention during the preschool years is often more effective in shaping lasting dispositions toward learning.

2.3. Socio-Emotional Learning in Early Childhood

Socio-emotional learning (SEL) is increasingly recognized as a cornerstone of early childhood development (Wilkinson & Kao, 2019), essential for preparing children to thrive in school and social life. SEL includes empathy, cooperation, communication, and the ability to regulate emotions. Demonstrated that preschool SEL programs contribute to improved peer interaction, stronger relationships, and reduced behavioural problems. Other studies highlight the role of cooperative play and group-based activities in building emotional resilience and fostering inclusivity.

In Indonesia, socio-emotional development is emphasized in the national ECE framework, yet systematic implementation remains uneven. Research on how socio-emotional outcomes are cultivated specifically within science learning is limited. Most existing studies examine SEL in general play-based or character education contexts, leaving unanswered questions about how structured learning models and techniques, such as group-based or exploration-based science learning, can intentionally develop these attitudes.

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2.4. Science Learning and Pedagogical Models

Science learning in ECE is particularly powerful because it naturally combines cognitive and socio-emotional domains (Singh & Muis, 2024). Through observation, experimentation, and inquiry, children not only develop curiosity and critical thinking but also learn to collaborate, share ideas, and respect others' perspectives (Chang-Tik et al., 2024). Group-based learning models encourage teamwork and idea-sharing, while center-based models provide structured environments that promote active engagement, decision-making, and creativity.

Learning techniques also play an important role. Exploration-based techniques encourage children to observe, investigate, and create, nurturing cognitive engagement (Höyng, 2021). Direct experience-based techniques, on the other hand, immerse children in real-life activities, strengthening both practical understanding and socio-emotional bonds (Priadi & Fatria, 2024). While individual models and techniques have been shown to produce benefits, few studies test their coherence, that is, how specific combinations work together to foster cognitive and socio-emotional learning attitudes simultaneously.

2.5. Identified Research Gap

Although existing literature provides valuable insights into ECE models, techniques, and learning outcomes, most studies examine these elements in isolation (Hendra & Fahlevi, 2024; Nafiqoh & Wulansuci, 2021). Research tends to evaluate either learning models or techniques without considering how they interact. Moreover, the Indonesian context remains underexplored, despite its unique blend of community-driven institutions and cultural emphasis on holistic education. International studies offer broad lessons, but localized evidence is necessary to guide policy and practice in Indonesia. The lack of systematic, empirical research on model–technique coherence leaves teachers with limited guidance for designing effective learning experiences.

2.6. Problem Statement

The literature indicates that learning models and techniques each influence children's development, yet the question of which combinations are most effective remains unanswered (Santyasa et al., 2022). Without this evidence, educators risk relying on fragmented approaches that may neglect either cognitive or socio-emotional outcomes (Suastra et al., 2017). For Indonesian ECE, where private institutions dominate and pedagogical quality varies, this gap is exceptionally pressing. A systematic evaluation of how learning models and techniques interact in science education is therefore needed to provide practical guidance for teachers and to support the holistic development of young learners.

3. Methodology

3.1. Research Design

This study employed a quantitative ex post facto design, also referred to as causal-comparative research. The ex post facto approach, which literally means "after the fact," is used to investigate cause-and-effect relationships where the researcher cannot manipulate the independent variable. According to this design, it is particularly suitable when variables are naturally occurring and experimental control is not possible. In educational research, this design is widely used because it would be neither ethical nor feasible to randomly assign children to specific learning models or techniques. Instead, the researcher analyses existing practices to identify their association with learning outcomes. In this study, the learning models and techniques already applied in Early Childhood Education (ECE) institutions were examined to determine their coherence with children's cognitive and socio-emotional learning attitudes. This design preserved the ecological validity of classroom practices while enabling systematic analysis of the relationships among variables.

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3.2. Study Context and Participants

The research was conducted in Banten Province, Indonesia, where the majority of ECE institutions are privately managed. The province includes 4,159 formal and 4,240 non-formal institutions, reflecting significant community involvement in early education. Formal institutions consist of kindergartens and early-grade schools, while non-formal institutions include playgroups and community-based centres. Given this diversity, a proportionate stratified random sampling technique was used to ensure representation of both tracks. From this population, a sample of 199 institutions was selected, consisting of 99 formal and 100 non-formal institutions. Each institution was represented by one teacher or administrator directly involved in implementing science learning activities. Thus, a total of 199 respondents participated in the study. The demographic profile of participants indicated that the majority were female (86%), consistent with national trends in the ECE workforce, with an average of 7.5 years of teaching experience. The sample included both urban (58%) and rural (42%) institutions, providing a balanced representation of contexts with different resource levels and pedagogical conditions.

3.3. Data Collection Procedures

Data collection took place between March and June 2024. Ethical approval was obtained from the Research Ethics Committee of Universitas Sultan Ageng Tirtayasa (Approval No.: UST-EC/2025/034), and official permission was secured from provincial education authorities. Institutional consent was obtained from the participating schools, and written informed consent was obtained from all respondents. The structured questionnaire was administered through both in-person visits and secure online platforms. To minimize misinterpretation, trained research assistants guided participants during data collection sessions. A pilot test was conducted with 30 teachers from institutions not included in the final sample, which helped refine item clarity, translation, and cultural appropriateness. Feedback from the pilot confirmed the instrument's suitability for the target population. During the main data collection, responses were recorded anonymously, and participants were informed of their right to withdraw at any time. This procedure enhanced response accuracy and reduced potential sources of bias.

3.4. Instruments

The primary instrument was a structured questionnaire comprising 45 items, rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). The items were adapted from validated instruments used in prior early childhood and science education studies and contextualized for Indonesia through expert review. The instrument measured three broad domains: learning models, learning techniques, and learning attitudes.

For the learning models, four constructs were included: group-based learning model (GLM, 4 items), corner-based learning model (ALM, 3 items), area-based learning model (WLM, 3 items), and centre-based learning model (CLM, 4 items). Indicators covered dimensions such as student activity, discussion engagement, cognitive development, symbolic reasoning, play environments, and decision-making. For the learning techniques, exploration-based technique (ELT, 4 items) and direct experience-based technique (DLT, 3 items) were measured. These included indicators of observing, investigating, play activities, and real-life engagement. Finally, learning attitudes were measured across three constructs: scientific attitude and interest (SAI, 3 items, e.g., curiosity, honesty, critical thinking), cognitive learning attitude (CLA, 4 items, e.g., memory, comprehension, analysis, creativity), and socio-emotional learning attitude (SLA, 3 items, e.g., communication, cooperation, empathy).

Reliability and validity of the instrument were confirmed through pilot testing and statistical analysis. Cronbach's α values for all constructs exceeded 0.80, indicating strong internal consistency.

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Confirmatory Factor Analysis (CFA) demonstrated that factor loadings were generally above 0.70. Construct reliability (CR) values were all above 0.70, while Average Variance Extracted (AVE) values exceeded 0.50, confirming convergent validity.

3.5. Analytical Techniques

Data analysis was conducted using Structural Equation Modeling (SEM) with LISREL 8.80. SEM was selected because it allows simultaneous analysis of measurement and structural models, making it suitable for testing complex relationships among latent variables. The analytical process involved several stages. First, preliminary data screening was conducted to assess missing values, outliers, and normality. Missing data were minimal and handled using mean imputation, while skewness and kurtosis values fell within the acceptable range of ±2. Second, the measurement model was tested using CFA to assess construct validity. Indicators with factor loadings below 0.70 were carefully reviewed and excluded if necessary. Third, the structural model was evaluated to test the hypothesized relationships between learning models, learning techniques, and learning attitudes. Fourth, mediation analysis was performed using Sobel's z-test to examine whether learning techniques mediated the relationships between models and attitudes.

3.6. Model Fit Indices (with formulas)

Before testing hypothesized paths, overall model–data fit was evaluated using common SEM indices. Following, we report the chi-square ratio (χ^2/df), Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Acceptable thresholds are: $\chi^2/df < 3.00$; CFI, TLI ≥ 0.90; RMSEA ≤ 0.08; SRMR ≤ 0.08.

Definitions

1. Chi-square ratio

$$\frac{x^2}{df} = \frac{x^2_{model}}{df_{model}}$$

2. CFI (incremental fit comparing the target model to the null/independence model)

$$CFI = 1 - \frac{x^2_{model} - df_{model}}{x^2_{null} - df_{null}}$$

3. TLI (non-normed fit index; penalizes lack of parsimony)

$$TLI = \frac{\frac{X^2_{null}}{df_{null}} - X^2_{model}\ /df_{model}}{\frac{X^2_{null}}{dff_{null}} - 1}$$

RMSEA (badness-of-fit per degree of freedom; population discrepancy) Let N be the sample size and let $\lambda = max(X^2_{model} - df_{model})$the noncentrality estimate. Then

$$RMSEA = \sqrt{\frac{\lambda}{df_{model}\ (N-1)}} = \sqrt{max\left(\frac{x^2_{model} - df_{model}}{df_{model}\ (N-1)}, 0\right)}$$

Report 90% CI based on the noncentral χ2\chi^{2}χ2 distribution when available, and p_closep_\text{close}p_close for the test RMSEA ≤0.05\le 0.05≤0.05.)

SRMR (average standardized residual between observed and model-implied correlations) For $p$observed variables with sample correlation matrix $R = (rij)$and model-implied correlation matrix $R\hat{} = (r\hat{}ij)$,

Results (this study, N=199N=199N=199)

$$\chi 2/df = 2.11, CFI = 0.94, TLI = 0.92, RMSEA = 0.057, SRMR = 0.046$$

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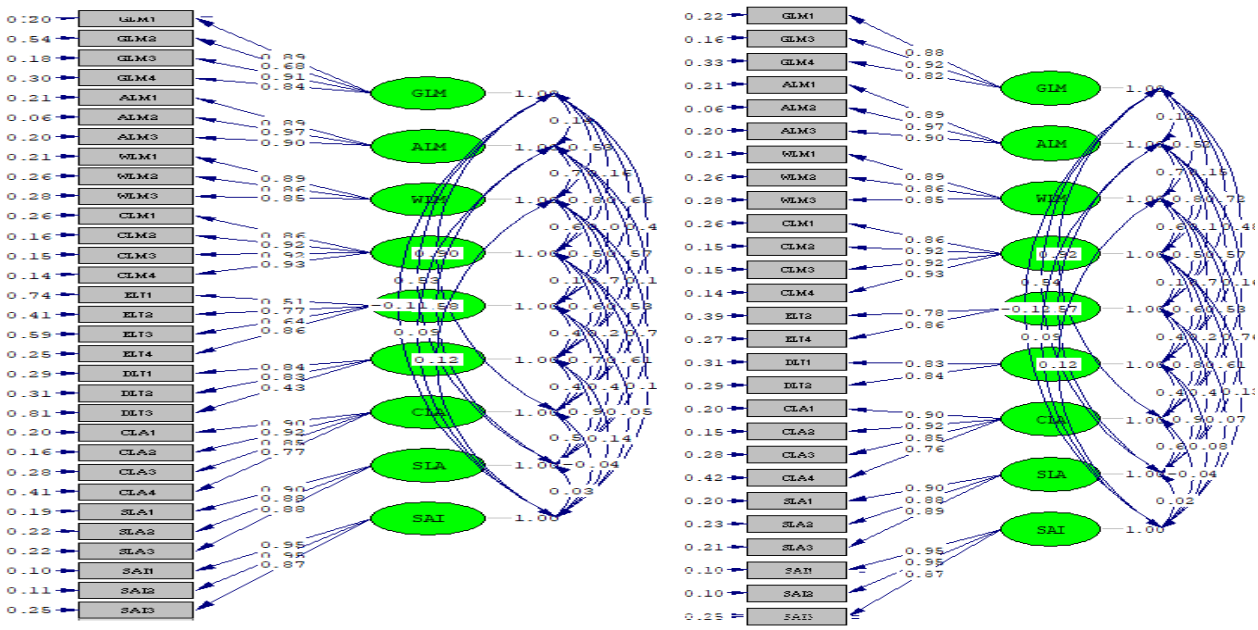
All indices meet recommended benchmarks ($\chi^2/df < 3.0$; $CFI/TLI \geq 0.90$; $RMSEA \leq 0.08$; $SRMR \leq 0.08$),indicating acceptable–good global fit and supporting the adequacy of both the measurement and structural models.

4. Results

4.1. Validity and Reliability Test of Data Indicators

The results of the indicator analysis for the variables of learning models, learning techniques, scientific attitudes and interest in science learning, and early childhood learning attitudes in Banten Province are presented in Figure 1. Figure 1.a shows all indicators for each variable, while Figure 1.b displays only the indicators with loading factors greater than 0.7. Out of the nine variables analysed, four indicators across three variables had loading factors below 0.7: activeness in discussion (GLM2), observing (ELT1), imitating (ELT3), and active participation in learning (DLT3). For indicators that met the threshold of > 0.7, validity and reliability were assessed using Equations (1) and (2).

The results for Construct Reliability (CR) and Average Variance Extracted (AVE) for each variable are as follows: Group-Based Learning Model (GLM): CR = 0.91, AVE = 0.76; Corner-Based Learning Model (ALM): CR = 0.94, AVE = 0.84; Area-Based Learning Model (WLM): CR = 0.90, AVE = 0.75; Centre-Based Learning Model (CLM): CR = 0.95, AVE = 0.82; Exploration-Based Technique (ELT): CR = 0.80, AVE = 0.67; Direct Experience-Based Technique (DLT): CR = 0.82, AVE = 0.70; Cognitive Learning Attitude (CLA): CR = 0.92, AVE = 0.74; Socio-Emotional Learning Attitude (SLA): CR = 0.92, AVE = 0.79; Scientific Attitude and Interest (SAI): CR = 0.94, AVE = 0.85. Based on the standard criteria of CR > 0.7 and AVE > 0.5, all variables were deemed valid and reliable. These findings indicate that the group-based learning model, which encompasses student activities within groups, sharing of ideas and opinions, and shared responsibility, is coherent with science learning in early childhood education. Group-based learning in science supports interaction and collaboration among children. In addition, exploration-based learning techniques, including investigating, creating, and imagining, as well as direct experience-based techniques, including play activities and real-life experiences, demonstrated coherence with science learning in fostering both cognitive and socio-emotional learning attitudes. These techniques are intentionally designed to encourage observation, investigation, and direct engagement with the environment.



(a) (b)

Figure 1. Results of Validity and Reliability Testing

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To analyse scientific attitudes and interest in science learning, this study assessed learning models with learning techniques as mediating variables. The results of both the direct and indirect influence of learning models on scientific attitudes and interest in early childhood science learning in Banten Province are presented in Figure 2.

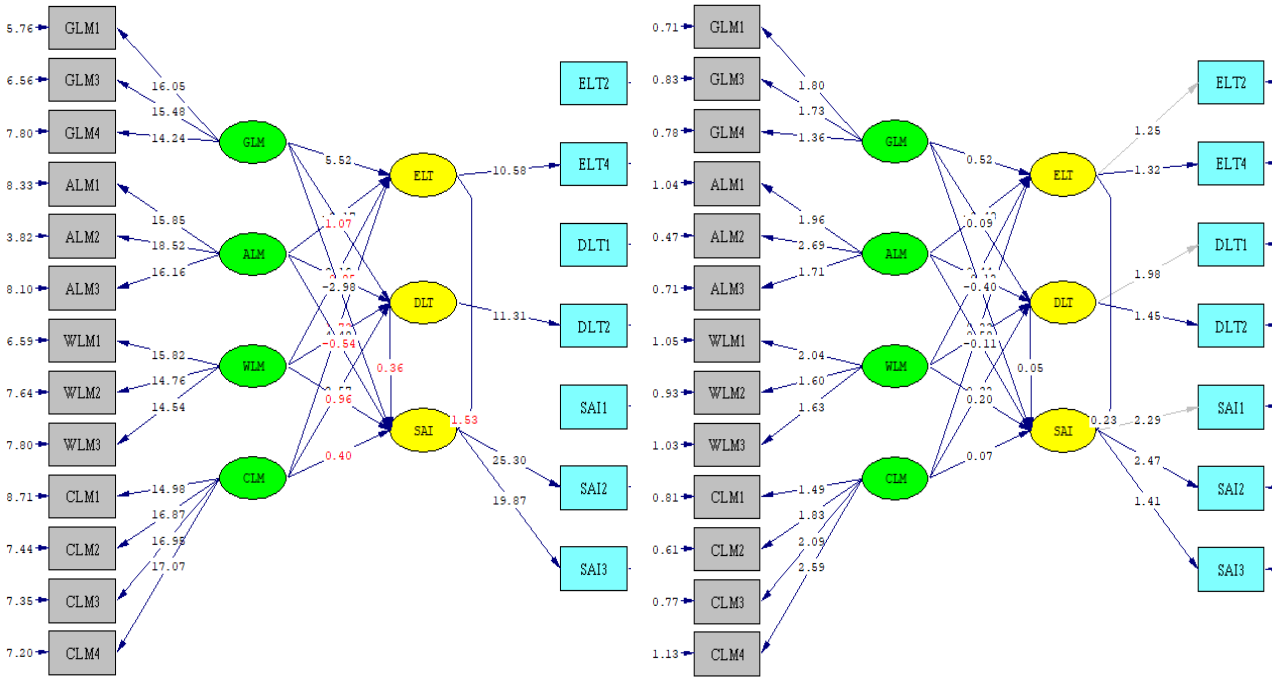

Figure 2. Models and Techniques of Science Learning

Figure 2 displays the constellation of learning models, scientific attitudes, and interests, with exploration and direct experience techniques as mediators. Figure 2 presents the *t*-test results, where red values indicate t-values smaller than the critical *t*-value. With a sample size of 199 and seven variables, the critical *t*-value is 1.974. Values in black indicate significant relationships ($t > 1.974$), while red indicates non-significance ($t < 1.974$). From Figure 2. a, only the group-based learning model has a direct effect on children's scientific attitudes and interest in science learning. Figure 2 b presents the linear relationships among the exogenous, endogenous, and mediating latent variables. Using Equation (3), the linear regression equation for scientific attitude and interest (SAI) with six predictors is as follows: SAI = 0.23ELT + 0.052DLT − 0.40GLM − 0.11ALM + 0.20WLM + 0.067CLM. From this equation, the indirect effects of the learning models on scientific attitude and interest are mediated by the learning techniques.

The indirect effect of learning models on scientific attitudes and interest in science learning through learning techniques was analysed using Equation (4). The regression coefficient for the group-based learning model (GLM) was $a = –0.40$ with a standard error of estimation (SE_a) = 0.13. In contrast, the regression coefficient for the exploration-based learning technique (ELT) was $b = 0.23$ with a standard error of estimation (SE_b) = 0.15. Based on Equation (4), the resulting *z*-value = –1.372, with a standard error of 0.067 and a *p*-value = 0.169. Meanwhile, for the direct experience-based learning technique (DLT), the coefficient was $b = 0.052$, $SE_b = 0.14$, yielding $z = –0.369$, standard error = 0.056, and *p*-value = 0.712. These results indicate that $z < 1.97$ and $p > 0.05$, implying that neither exploration-based nor direct experience-based learning techniques mediate the relationship between the group-based learning model and scientific attitudes and interest among early childhood learners in science education. Furthermore, the regression coefficient for the corner-based learning model (ALM) was $a = 0.11$, $SE_a = 0.20$, and the regression coefficient for ELT was $b = 0.23$, $SE_b = 0.15$,

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yielding z = 0.518, standard error = 0.049, and p = 0.605. For DLT, b = 0.052, SE_b = 0.14, z = 0.308, standard error = 0.019, p = 0.758. Again, the z-values are lower than 1.97, and the p-values are above 0.05, indicating that neither learning technique mediates the relationship between the corner-based model and scientific attitudes and interests. Similarly, the regression coefficients for the area-based learning model (WLM) were a = 0.20, SEa = 0.20, and for ELT were b = 0.23, SE_b = 0.15, resulting in z = 0.838, standard error = 0.055, and p = 0.402. For DLT, b = 0.052, SE_b = 0.14, z = 0.348, standard error = 0.029, and p = 0.727. These results likewise demonstrate a lack of mediation. In the case of the centre-based learning model (CLM), the regression coefficient was a = 0.067, SE_a = 0.17, and for ELT, b = 0.23, SE_b = 0.15, producing z = 0.367, standard error = 0.042, and p = 0.714. For DLT, b = 0.052, SE_b = 0.14, the result was z = 0.270, standard error = 0.013, and p = 0.787. These findings also show that the mediating effects were not statistically significant.

Based on the above analyses, it can be concluded that neither exploration-based nor direct experience-based learning techniques mediate the effects of group-, corner-, area-, or centre-based learning models on scientific attitudes and interest in science learning among early childhood learners. However, the group-based learning model was found to have a direct significant effect on scientific attitudes and interest. This aligns with previous research, which reported that group-based learning positively influences science learning outcomes. The group-based model is particularly effective in fostering curiosity, honesty, and critical thinking in young children. It demonstrates strong coherence with science learning by encouraging collaboration, idea exchange, and active participation among learners.

4.2. Coherence Test of Learning Models and Techniques with Learning Attitudes

To analyse the coherence between learning models and learning attitudes, both cognitive and socio-emotional learning techniques were used as mediating variables. The results of the analysis in Early Childhood Education (ECE) institutions in Banten Province are illustrated in Figure 3.

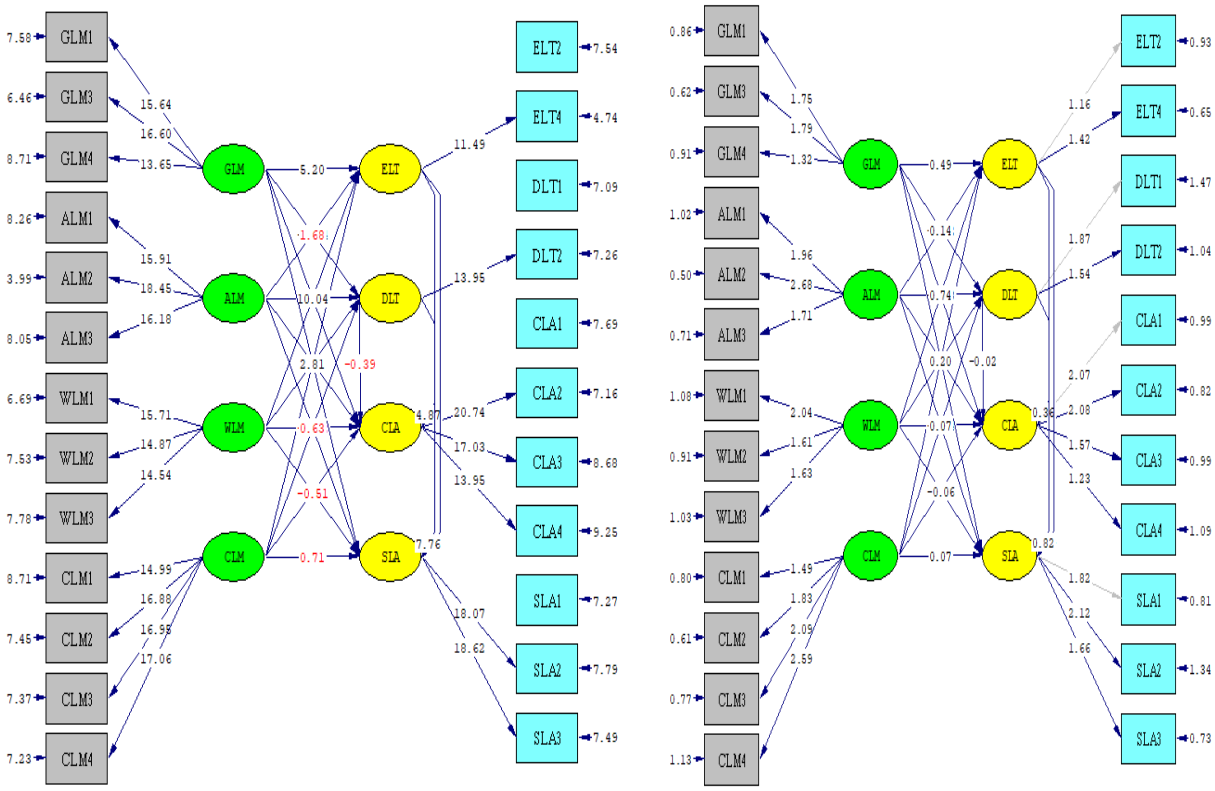

Figure 3. Models and Techniques of Learning to Foster Learning Attitudes

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Figure 3 presents the constellation of learning models in relation to cognitive and socio-emotional learning attitudes, with exploration-based and direct experience-based learning techniques functioning as mediating variables. In Figure 3, the *t*-test (*t*-value) results between variables are shown, where red-coloured values indicate *t*-values less than the critical *t*-value. In comparison, black-coloured values signify *t*-values greater than the critical value. The critical *t*-value for a sample size of 199 with eight variables is 1.972. Based on the figure, it is evident that among the four learning models, some demonstrate both direct and indirect effects on learning attitudes.

The group-based learning model (GLM) was found to have a direct effect on both cognitive learning attitude (CLA) and socio-emotional learning attitude (SLA) of early childhood learners in Banten Province. Additionally, the corner-based learning model (ALM) had a direct effect on cognitive learning attitude (CLA).

In Figure 3.b, the mediating effects of learning techniques on the relationship between learning models and learning attitudes are presented. The linear relationship between cognitive learning attitude (CLA) and learning models and techniques is as follows: CLA = 0.36ELT - 0.025DLT + 0.74GLM + 0.0058ALM - 0.14WLM + 0.17CLM. Meanwhile, the linear relationship for socio-emotional learning attitude (SLA) is: SLA = 0.0027ELT + 0.82DLT + 0.20GLM + 0.067ALM - 0.059WLM + 0.067CLM. Based on these two equations, and by applying Equation (4), the mediating effects of ELT and DLT on CLA and SLA were obtained. For the cognitive learning attitude (CLA), the regression coefficient for the group-based learning model (GLM) was *a* = 0.74 (SEa = 0.073), and the regression coefficient for the exploration-based learning technique (ELT) was b = 0.36 (SEb = 0.074). Using Equation (4), a *z*-value of 4.39 with a standard error of 0.061 and a *p*-value of 0.00001155 was obtained. Since the *z*-value (4.39) is greater than the critical *t*-value (1.97) and the *p*-value (0.00001155) is less than 0.05, it indicates a significant mediating effect of ELT on the relationship between GLM and CLA. On the other hand, the regression coefficient for the direct experience-based technique (DLT) was *b* = -0.025, with SEb = 0.063, yielding a z-value of -0.39, a standard error of 0.047, and a p-value of 0.692. This shows that the *z*-value is less than 1.97 and the *p*-value is greater than 0.05, indicating no significant mediating effect of DLT. Thus, it can be concluded that the group-based learning model has an indirect effect on cognitive learning attitude through the exploration-based learning technique. The technique serves as a mediator in the relationship between the group-based model and cognitive learning attitude, whereas the direct experience-based technique does not.

Furthermore, for the corner-based learning model (ALM), the regression coefficient was *a* = 0.0058 with SE_a = 0.092, and for ELT, *b* = 0.36 with SE_b = 0.074, resulting in a *z*-value = 0.063 with a standard error = 0.033 and *p*-value = 0.949. Meanwhile, for DLT, *b* = -0.025 with SE_b = 0.063, the *z*-value = -0.062, standard error = 0.002, and *p*-value = 0.950. These results indicate that neither learning techniques mediate the effect of the corner-based learning model on cognitive learning attitude. For the area-based learning model (WLM), the regression coefficient was *a* = -0.14 with SE_a = 0.095, and for ELT, *b* = 0.36 with SE_b = 0.074, the resulting *z*-value = -1.41 with standard error = 0.036 and *p*-value = 0.158. For DLT, *b* = -0.025 with SE_b = 0.063, the *z*-value = 0.38 with standard error = 0.009 and *p*-value = 0.702. These values indicate the absence of a mediation effect for both techniques. For the centre-based learning model (CLM), the regression coefficient was *a* = 0.17 with SE_a = 0.078, and for ELT, *b* = 0.36 with SE_b = 0.074, yielding a *z*-value = 1.99, a standard error = 0.031, and a *p*-value = 0.047. Since $z = 1.99 > 1.97$ and $p = 0.047 < 0.05$, this demonstrates a significant mediating effect of ELT. However, for DLT, *b* = -0.025 with SE_b = 0.063, the *z*-value = 0.39 with standard error = 0.011 and *p*-value = 0.696, showing no significant mediation. Based on these findings, it can be concluded that exploration-based learning techniques mediate the effects of both group-based and centre-based learning models on cognitive learning attitudes. Therefore, these two models, in combination with exploration-based techniques, are coherent for fostering cognitive learning attitudes among early childhood learners in Banten Province. Both models emphasize

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interaction and exploration. Group-based learning promotes peer interaction, while centre-based learning provides a rich and stimulating environment.

For socio-emotional learning attitude (SLA), the regression coefficient for the group-based learning model (GLM) was a = 0.20 with SE_a = 0.070, and for ELT, b = 0.0027 with SE_b = 0.072; the z-value was 0.037 with a standard error of 0.014 and a p-value of 0.970. For DLT, b = 0.82 with SE_b = 0.11; the z-value = 2.67, which is greater than the critical value; standard error = 0.061; p-value = 0.008. This shows that DLT significantly mediates the relationship between GLM and SLA. For the corner-based learning model (ALM), a = 0.067 with SE_a = 0.11, and for ELT, b = 0.0027 with SE_b = 0.072, the z-value = 0.037 with standard error = 0.005 and p-value = 0.97. For DLT, b = 0.82 with SE_b = 0.11, the z-value = 0.61 with standard error = 0.091 and p-value = 0.544. These results indicate no mediation. For the area-based learning model (WLM), a = -0.059 with SE_a = 0.11, and for ELT, b = 0.0027 with SE_b = 0.072, the z-value = -0.037 with standard error = 0.04 and p-value = 0.97. For DLT, b = 0.82 with SE_b = 0.11, the z-value = -0.535 with standard error = 0.09 and p-value = 0.593. These also indicate no mediation. For the centre-based learning model (CLM), a = 0.067 with SE_a = 0.094, and for ELT, b = 0.0027 with SE_b = 0.072, the z-value = 0.037 with standard error = 0.005 and p-value = 0.97. For DLT, b = 0.82 with SE_b = 0.11, the z-value = 0.71 with standard error = 0.08 and p-value = 0.478. Again, no mediation is indicated. In summary, only the group-based learning model demonstrates an indirect effect on socio-emotional learning attitude through the direct experience-based learning technique. This indicates that DLT plays a mediating role in the relationship between GLM and SLA in science learning. Therefore, the group-based learning model combined with the direct experience-based technique is coherent for fostering socio-emotional learning attitudes in early childhood learners in Banten Province. This finding is supported by previous research, which concludes that children's socio-emotional development can be enhanced through cooperative learning methods.

5. Discussion

5.1. Summary of key findings

This study examined how four learning models (group-, corner-, area-, and center-based) interact with two learning techniques (exploration- and direct-experience–based) to cultivate three outcomes in early childhood science learning: scientific attitude and interest (SAI), cognitive learning attitude (CLA), and socio-emotional learning attitude (SLA). Three robust patterns emerged. First, the group-based model exhibited a direct positive effect on SAI (Alam & Mohanty, 2023). Second, CLA improved indirectly through exploration-based techniques embedded within group- and centre-based structures. Third, SLA improved indirectly through direct-experience techniques layered onto the group-based model (Husna et al., 2024). Corner- and area-based models showed limited effects when techniques and outcomes were modelled simultaneously. These relationships were estimated on a valid and reliable measurement model (all CR > .70; AVE > .50) and a well-fitting structural model (χ^2/df = 2.11; CFI = .94; TLI = .92; RMSEA = .057; SRMR = .046), lending confidence to the results.

5.2. Interpretation in light of prior research

The direct link from group-based learning to SAI is pedagogically consistent: small-group structures organize joint attention (Jones, 2007), peer explanation, and negotiated meanings — mechanisms known to trigger curiosity, honest reporting of observations, and critical questioning — the very components of SAI used here (cf. cooperative approaches in science learning). For CLA, the significant exploration mediation within group and centre structures indicates that inquiry opportunities (observe–investigate–create) are the engine of cognitive gains; groups supply dialogic regulation and shared strategies, while centres provide materials and scaffolded prompts that make exploration frequent and repeatable (O'Keeffe et al., 2021). For SLA, the direct-experience × group pathway suggests that doing together (shared manipulation of materials, turn-taking, co-managing

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tasks) recruits communication, cooperation, and empathy, as indicated by the SLA indicators used here—converging with the literature on learning through play and cooperative activity. The limited effects of corner/area models likely reflect implementation variability and lower instructional density; without consistent exploration scaffolds or structured joint activity, effects on CLA or SLA can diffuse.

5.3. What this study adds (unique contribution)

Most prior work examines learning models or techniques in isolation. This study provides a model–technique coherence map showing that targeted outcomes arise from specific pairings: (group or center) + exploration → cognition (CLA), and group + direct experience → socio-emotion (SLA). It also contributes SEM-based evidence with strong measurement quality and acceptable global fit, strengthening interpretability within an ex post facto design (Goretzko et al., 2023). Finally, it offers localized evidence from 199 ECE institutions in Banten, an under-represented, community-driven context, thereby extending the generalizability of early science pedagogy beyond Western systems.

5.4. Practical implications

For teachers, to build cognition, embed exploration cycles (observe–investigate–create) into group tasks and centre rotations (e.g., rotating inquiry stations with simple data sheets and peer-explanation roles). To promote socio-emotion, schedule direct-experience modules (e.g., gardening, cooking, building) within stable small groups and assign social roles (materials leader, recorder, encourager) to deliberately practice cooperation and empathy (Wang & Zhang, 2023). For leaders/curriculum planners, specify model-technique pairings in scope-and-sequence documents and monitor exploration fidelity and the quality of joint activity as proximal drivers of CLA/SLA. For professional development, prioritize skills in orchestrating exploration prompts, facilitating group talk, and designing direct-experience routines aligned to social goals.

5.5. Limitations and future research

The ex post facto design limits strong causal inference; randomized or staggered-start trials could test the identified pairings more rigorously (Rosenbaum, 2025). Outcomes relied on teacher reports; adding direct child assessments and in-situ observations would triangulate effects. Future work should measure fidelity of implementation, examine moderators (age, class size, urban–rural context), and prototype low-cost routines to scale coherent model–technique pairings across heterogeneous ECE settings.

5.6. Contributions to the Literature

This study advances the field in three ways. (1) Coherence framework: it specifies which model–technique combinations matter for which outcomes in early science learning GLM/CLM + exploration for cognition (CLA), and GLM + direct experience for socio-emotion (SLA), moving beyond single-factor evaluations standard in prior studies (Nicholls, 2004). (2) Methodological rigor: it delivers validated constructs (CR/AVE) and acceptable global fit (CFI, TLI, RMSEA, SRMR), demonstrating how SEM can reveal mediated mechanisms (techniques) between arrangements (models) and outcomes in ECE. (3) Contextual extension: it contributes evidence from Indonesia (Banten), where private/community provision is high, enriching the largely Western-centric literature with findings that remain actionable in resource-variable systems. Editorial note: move any content currently labelled under “Solutions” that claims novelty or scholarly advance into this Contributions section to align with journal conventions.

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5.7. Recommendations

For classroom practice. (i) To strengthen CLA, implement weekly exploration cycles embedded in group or centre routines; use simple observation sheets and peer-explanation turns to externalize thinking. (ii) To strengthen SLA, schedule direct-experience projects (e.g., cooking day, planting day) in small, stable groups with assigned social roles and reflection prompts to surface cooperation and empathy. (iii) Use low-cost centre kits (magnifiers, measuring cups, recycled materials) and prompt cards to standardize exploration across classrooms with variable resources.

For leadership and policy. (i) Embed model–technique pairing guidance in curriculum documents (e.g., "GLM/CLM + exploration for cognition; GLM + direct experience for socio-emotion"). (ii) Align teacher training to three core competencies: designing exploration prompts, facilitating group discourse, and structuring direct-experience routines tied to SEL goals. (iii) Monitor fidelity using short observation rubrics that track exploration density and quality of joint activity rather than only time-on-task.

For future research. (i) Conduct quasi-experimental or randomized studies to verify causal pathways; (ii) integrate child-level assessments (cognitive tasks, SEL rubrics) and video-based interaction analyses; (iii) test moderators (class size, age, teacher experience), and (iv) evaluate scalability of low-resource center kits and role-based group routines across urban and rural settings.

6. Conclusion

To foster cognitive and socio-emotional learning attitudes among early childhood learners in Banten Province, four learning models and two learning techniques were implemented in the context of science education. The group-based learning model was found to be coherent with the development of scientific attitudes and interests, as well as with cognitive and socio-emotional learning. This model includes activities such as collaboration, sharing ideas and opinions, and shared responsibility. Meanwhile, the centre-based learning model aligned with both types of learning attitudes through the provision of a play environment, support for active and creative engagement, and encouragement of children to make independent decisions. Specifically in science learning, the group-based model was effective in cultivating scientific attitudes and interest in young children. To enhance learning attitudes more broadly, both the group-based and centre-based models, when combined with exploration-based techniques, effectively fostered cognitive learning attitudes. In contrast, the group-based learning model combined with direct experience-based techniques proved effective in promoting socio-emotional learning attitudes among early childhood learners in Banten Province.

Declarations

Conflicts of Interest. The authors declare no conflict of interest.

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Ethical Approval. This study was approved by the Research Ethics Committee of Universitas Sultan Ageng Tirtayasa, Indonesia, with approval reference number UST-EC/2025/034. All procedures involving human participants complied with institutional and national research ethics standards.

Data Availability Statement. The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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