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From play to numeracy: exploring cognitive and pedagogical processes in early childhood learning

Muhamad Yusup Kurniansyah[1], Regina Meilani[2], Lita Nur Aryanti[3]*

[1,2] Institut Darul Falah, Bandung Barat, Indonesia
[3] RA Jauharul Huda, Bandung Barat, Indonesia
*Correspondence: E-mail: yusupkurniansyah@gmail.com

A B S T RAK

Perkembangan numerasi dini penting dalam pendidikan anak usia dini karena mendukung kemampuan berpikir logis dan kesiapan belajar anak. Penelitian ini mengeksplorasi proses kognitif anak dan peran pedagogis guru dalam pembelajaran berbasis bermain menggunakan pendekatan kualitatif dengan analisis tematik. Data diperoleh melalui observasi dan wawancara di RA Jauharul Huda. Hasil penelitian menunjukkan bahwa pembelajaran berbasis bermain mendukung numerasi dini melalui aktivitas eksploratif dan interaktif. Guru berperan dalam merancang aktivitas bermain, menggunakan media konkret, serta menerapkan guided play dan scaffolding. Penelitian ini menyimpulkan bahwa perkembangan numerasi dini berkembang melalui interaksi antara keterlibatan kognitif anak dan dukungan pedagogis guru dalam lingkungan belajar yang bermakna.

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A B S T R A C T

Early numeracy development is important in early childhood education because it supports children's logical thinking and school readiness. This study explored children's cognitive processes and teachers' pedagogical roles in play-based learning using a qualitative approach with thematic analysis. Data were collected through observations and interviews at RA Jauharul Huda. The findings showed that play-based learning supports early numeracy through exploratory and interactive activities. Teachers contributed by designing play activities, using concrete media, and applying guided play and scaffolding. The study concludes that early numeracy develops through the interaction between children's cognitive engagement and teachers' pedagogical support in meaningful learning environments.

Keywords:
Play-based learning,
Early numeracy,
Guided play,
Cognitive processes,
Early childhood pedagogy

1. INTRODUCTION

Learning in early childhood is an important stage in developing cognitive abilities, particularly in the aspect of early numeracy. Early numeracy is not only related to counting skills, but also involves logical thinking abilities, recognizing patterns, classifying objects, and understanding quantitative relationships in everyday life (Fitriana et al., 2021; Pahmi et al., 2023). These abilities serve as an important foundation for children's mathematical development at subsequent educational levels and are associated with future academic readiness (Bopo et al., 2023; Fikriyah et al., 2025; Iasha et al., 2024; Witono & Hadi, 2025).

However, numeracy learning in early childhood is still often conducted through conventional teacher-centered approaches that emphasize mechanistic counting exercises. Such approaches are less compatible with children's developmental characteristics because they provide minimal meaningful and contextual learning experiences (Dwijantie, 2026). Research indicates that overly structured learning without exploratory activities may hinder children's conceptual understanding of mathematics (Pahruroji et al., 2026).

As an alternative, play-based learning has become a widely recommended approach in early childhood education. Play enables children to learn through direct experience, exploration, and social interaction in enjoyable and meaningful situations (Hirsh-Pasek et al., 2020; Nopiana & Misgiyati, 2025; Saputra, 2024). From the perspective of Islamic education, play activities are also viewed as part of child developmental stimulation that can support children's cognitive, social, and character development holistically (Suhartini et al., 2024). In the context of numeracy, manipulative games, rule-based games, and physical activities integrated with mathematical concepts have been proven to help children understand concepts of numbers, patterns, and geometry more concretely (Dianti et al., 2025; Gawthorpe & Campbell Davidson, 2023; Grimmond et al., 2022). In addition to increasing learning engagement, play-based learning also contributes to the development of children's mathematical thinking abilities (Afwa, 2026).

Nevertheless, most previous studies have primarily focused on numeracy learning outcomes, such as counting skills or number recognition. Studies examining how children's cognitive processes are formed during play activities and how teachers' pedagogical processes support early numeracy development remain relatively limited. In fact, from a constructivist perspective, children's thinking processes and pedagogical interactions are important aspects of learning according to Vygotsky (Etnawati, 2021). Recent studies also emphasize that guided play and teacher scaffolding significantly influence children's cognitive development in play-based learning (M. Y. Chen et al., 2024; Ilan, 2026; Nurhidayati et al., 2026).

In addition, the development of early numeracy demonstrates variation among children, influenced by engagement, learning interest, and individual cognitive readiness (Ottay & Rocmah, 2025). Therefore, learning needs to be designed flexibly and adaptively according to children's developmental characteristics. Children's active involvement in the learning process is also an important factor in the successful development of early numeracy (Bakker et al., 2021).

Based on the explanation above, this study aims to explore children's cognitive processes and teachers' pedagogical processes in play-based learning to support the development of early numeracy in early childhood. Unlike previous studies that mainly focus on numeracy outcomes, this study examines the reciprocal relationship between children's cognitive processes and teachers' pedagogical processes within play-based learning. By analyzing these two dimensions simultaneously, this study provides a more comprehensive understanding of how early numeracy develops through the interaction between children's learning experiences and teachers' pedagogical support. Therefore, this study contributes conceptually to understanding play-based learning as a structured and meaningful pedagogical approach for early numeracy development in early childhood.

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2. METHOD

This study employed a qualitative approach with a case study design to explore children's cognitive processes and teachers' pedagogical practices in play-based learning for early numeracy development. The case study design was chosen because the research focused on a specific educational context, namely the implementation of play-based learning at RA Jauharul Huda, enabling an in-depth and contextual understanding of the phenomenon under investigation.

The study involved 34 children aged 5–6 years, consisting of 19 boys and 15 girls, as well as three female educators, including the principal. Participants were selected using purposive sampling because they were directly involved in the planning, implementation, and evaluation of play-based learning activities. The research site was selected because it consistently implements play-based learning and provides a context relevant to the study objectives.

Data were collected through observation, interviews, and documentation. Observations focused on play-based learning activities, teacher–child interactions, and children's numeracy-related behaviors. Interviews with teachers and the principal explored pedagogical strategies, teachers' roles, and children's numeracy development, while documentation was used to support and triangulate the findings.

Data were analyzed using thematic analysis, which is suitable for identifying and interpreting patterns in qualitative data (Nurjanah et al., 2022). The analysis involved data familiarization, initial coding, theme development, theme review and interpretation, and conclusion drawing. The analysis focused on themes related to children's cognitive processes, teachers' pedagogical practices, and learning interactions in play-based numeracy development. As illustrated in Figure 1, the thematic analysis framework guided the systematic interpretation of the data.

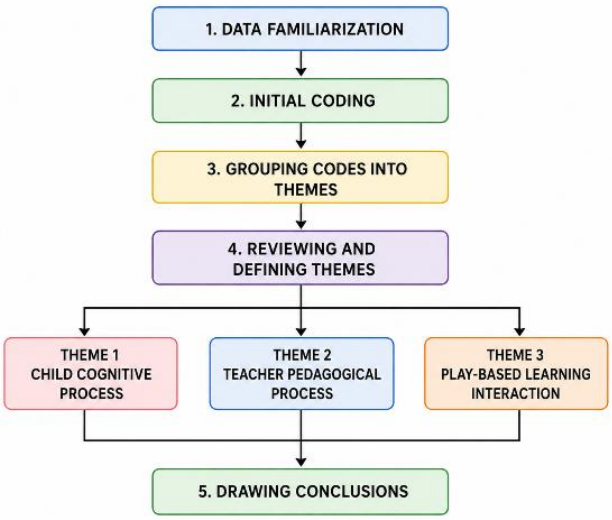

Figure 1. Data Analysis Framework

3. RESULT AND DISCUSSION

Children's Cognitive Processes in Play-Based Learning that Contribute to the Development of Early Numeracy

The results of the thematic analysis of observation and interview data indicate that children's cognitive processes in play-based learning develop through active engagement in exploratory, manipulative, and simple problem-solving activities. Based on the coding process and theme development, several major patterns were identified, demonstrating the relationship between play activities and early numeracy development. The initial coding results derived from the observation and interview data are presented in Figure 2.

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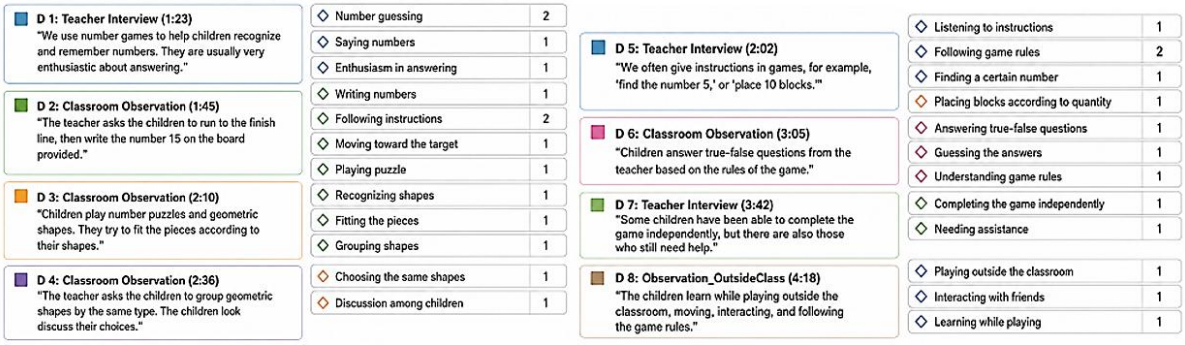

Figure 2. Initial Coding of Cognitive Process Data

As shown in Figure 2, the initial coding process identified several meaningful units related to number recognition, object classification, logical reasoning, and children's responses during play-based learning activities. These codes were subsequently grouped into broader categories and organized into several main themes, as presented in Figure 3.

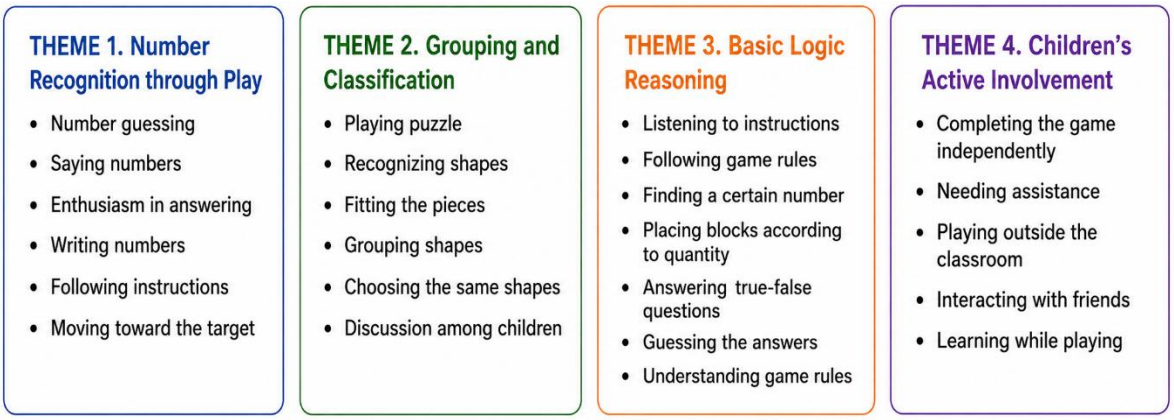

Figure 3. Development of Cognitive Process Themes

Based on the thematic structure illustrated in Figure 3, the first theme is the recognition of number symbols through guided play activities. Based on the observation results, teachers used number-guessing games and motor activities such as running toward the finish line while writing specific numbers. These activities demonstrate that children not only memorize number symbols, but also understand instructions, match symbols with visual representations, and connect physical activities with numerical thinking processes. Interview findings also revealed that the use of media such as puzzles, blocks, and outdoor games helped children recognize numbers while simultaneously developing logical thinking skills. In the coding process, activities such as guessing numbers, matching numbers, and writing numbers were categorized as forms of children's symbolic representation.

The second theme is classification ability through manipulative games. Teachers used geometric shape grouping activities to help children recognize similarities and differences in object characteristics. Activities such as grouping geometric shapes, selecting forms, and matching objects indicate categorical and logical thinking processes that form the basis of early numeracy development. Observation results also showed developmental variations among children, where some children were able to complete activities independently while others still required teacher assistance.

The next theme is simple logical reasoning in interactive play activities. Teachers used instruction-based games and guessing games to train children's thinking abilities. Activities such as understanding instructions, determining answers, and adjusting responses indicate that

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children were engaged in logical thinking and simple decision-making processes during play. The relationships among the identified cognitive process themes are illustrated in Figure 4.

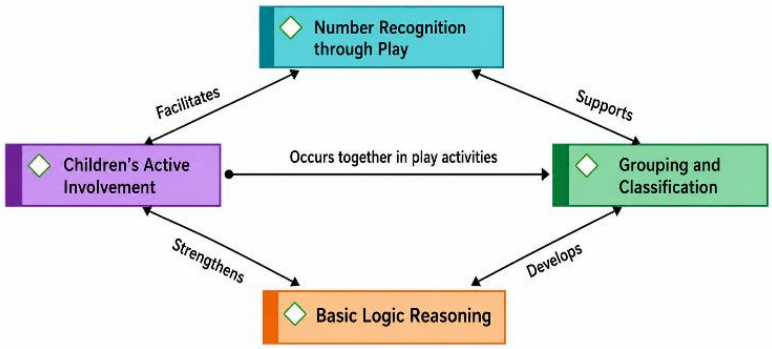

Figure 4. Cognitive Process Theme Network

As shown in Figure 4, the themes of number symbol recognition, classification skills, and simple logical reasoning are interconnected in supporting children's early numeracy development through play-based learning. Based on the overall analysis results, children's cognitive processes developed through direct learning experiences involving physical activities, social interaction, and manipulation of concrete objects. Play functioned not only as a recreational activity, but also as a learning mechanism that helped children construct contextual and meaningful numeracy understanding. These findings indicate that play-based learning supports the development of early numeracy as well as logical thinking and simple problem-solving abilities in early childhood.

Teachers' Pedagogical Processes in Designing and Implementing Play-Based Learning to Support Children's Early Numeracy Development

The results of the thematic analysis of interview and observation data indicate that teachers' pedagogical processes in play-based learning were carried out through the design of learning activities, the use of educational media, the provision of guidance during play activities, and the delivery of learning support to children. A summary of the data sources and the focus of the research information is presented in Figure 5.

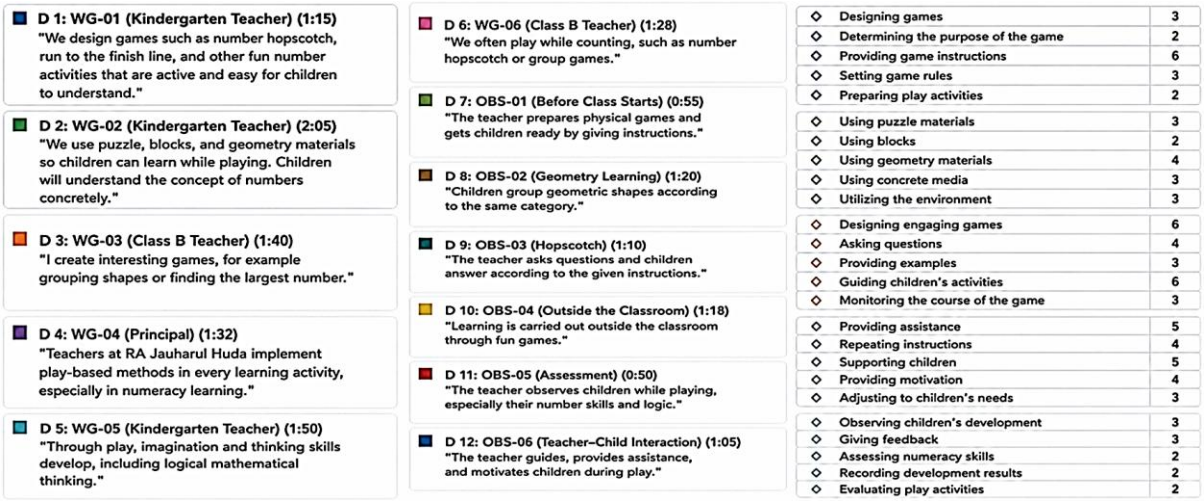

Figure 5. Initial Condition of Pedagogical Process Data

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As shown in Figure 5, the initial coding process identified several pedagogical activities related to learning design, the use of educational media, guided play practices, and learning support provided by teachers during play-based learning. Based on the coding process and theme development, several major patterns were identified that demonstrate how teachers facilitate the development of early numeracy through a play-based approach. The resulting thematic structure is presented in Figure 6.

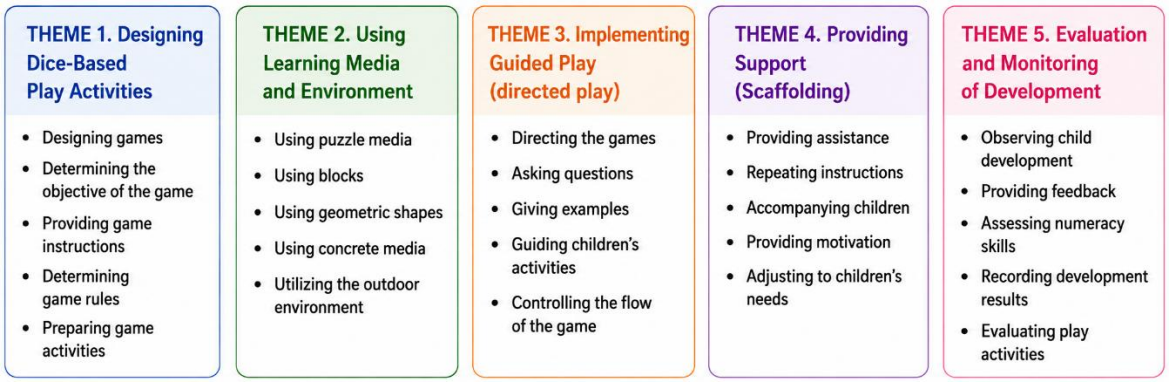

Figure 6. Development of Pedagogical Process Themes

Based on the themes illustrated in Figure 6, the first theme is the design of play activities directed toward numeracy learning objectives. Interview results showed that teachers designed games to help children recognize numbers, shapes, and simple patterns through activities such as number-guessing games, running games while writing numbers, and grouping geometric shapes. Activities such as giving game instructions, determining number targets, and organizing play activities were categorized as forms of pedagogical planning. Observation results also indicated that play activities had become a routine part of the learning process, positioning play as the primary learning strategy in early childhood education.

The second theme is the use of media and the learning environment as tools for stimulating early numeracy. Teachers used various media such as puzzles, blocks, geometric shapes, and outdoor games to help children understand numeracy concepts more concretely. Observations showed that children were more active and engaged when using play media compared to merely receiving verbal explanations. Activities such as using puzzles, playing with geometric forms, and engaging in outdoor play were categorized as forms of utilizing learning media and environments. These findings indicate that teachers functioned as facilitators who created learning environments that supported children's exploration.

The next theme is the implementation of guided play in learning activities. During the play process, teachers continued to provide instructions, questions, and guidance to ensure that play activities remained aligned with learning objectives. Activities such as giving instructions, directing games, and guiding children's activities were categorized as forms of guided play. This demonstrates a balance between children's freedom of exploration and teachers' pedagogical intervention.

The final theme is the provision of scaffolding during the learning process. Teachers provided assistance to children who experienced difficulties through repeated instructions, demonstrations, guidance, and motivation. Activities such as providing assistance, repeating instructions, and accompanying children were categorized as forms of pedagogical scaffolding. These findings indicate that play-based learning involves active pedagogical interaction that helps children achieve abilities they cannot yet accomplish independently. The relationships among the identified pedagogical themes are illustrated in Figure 7.

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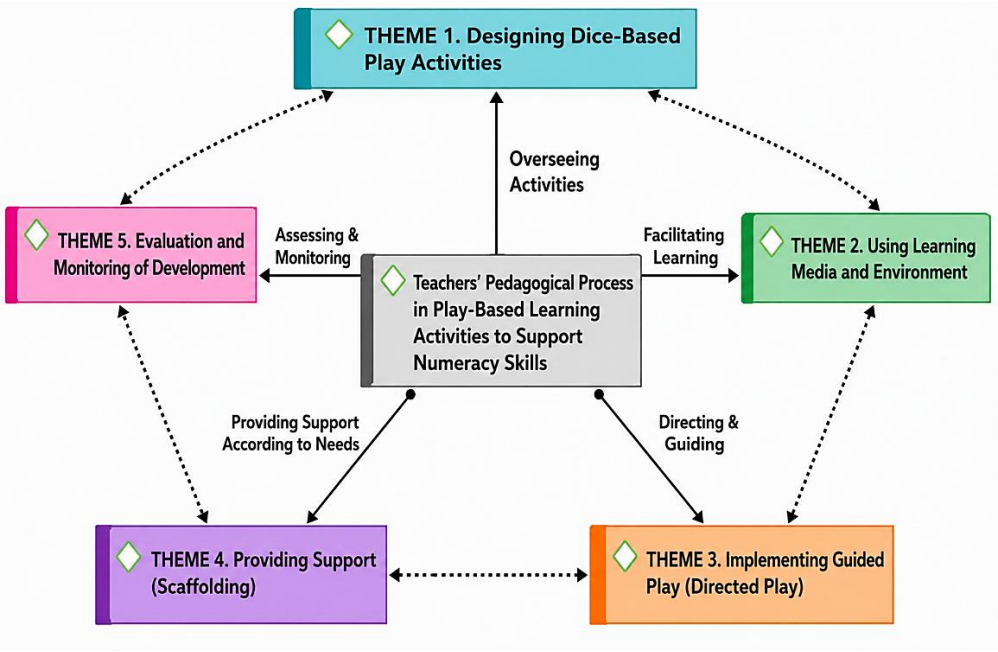

Figure 7. Pedagogical Process Theme Network

As shown in Figure 7, the themes of pedagogical planning, the use of learning media, guided play, and scaffolding are interconnected in supporting the implementation of play-based numeracy learning. Based on the overall analysis results, it can be understood that teachers' pedagogical processes in play-based learning were carried out through the design of structured activities, the use of contextual learning media, the implementation of guided play, and the provision of scaffolding throughout the learning process. These findings indicate that the success of play-based learning is not determined solely by the play activities themselves, but also by teachers' ability to design and facilitate learning experiences that support the development of early numeracy in early childhood.

The Relationship Between Children's Cognitive Processes and Teachers' Pedagogical Processes in Play-Based Learning for Developing Early Numeracy

The results of the thematic analysis indicate that the development of children's early numeracy in play-based learning is influenced not only by play activities themselves, but also by teachers' pedagogical processes in designing and facilitating children's learning experiences. The initial coding of the relationship between children's cognitive processes and teachers' pedagogical processes is presented in Figure 8.

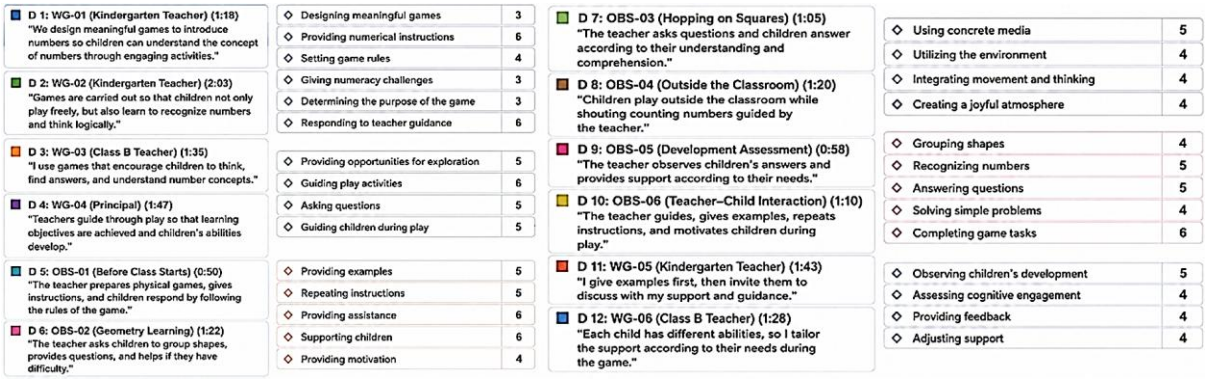

Figure 8. Coding of the Relationship Between Children's Cognitive Processes and Teachers' Pedagogical Processes

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As shown in Figure 8, several codes emerged that illustrate the interaction between children's cognitive engagement and teachers' pedagogical support during play-based learning activities. Based on the coding results and theme development, it was found that children's cognitive processes and teachers' pedagogical processes interact with one another in shaping meaningful numeracy learning experiences. The resulting thematic structure is presented in Figure 9.

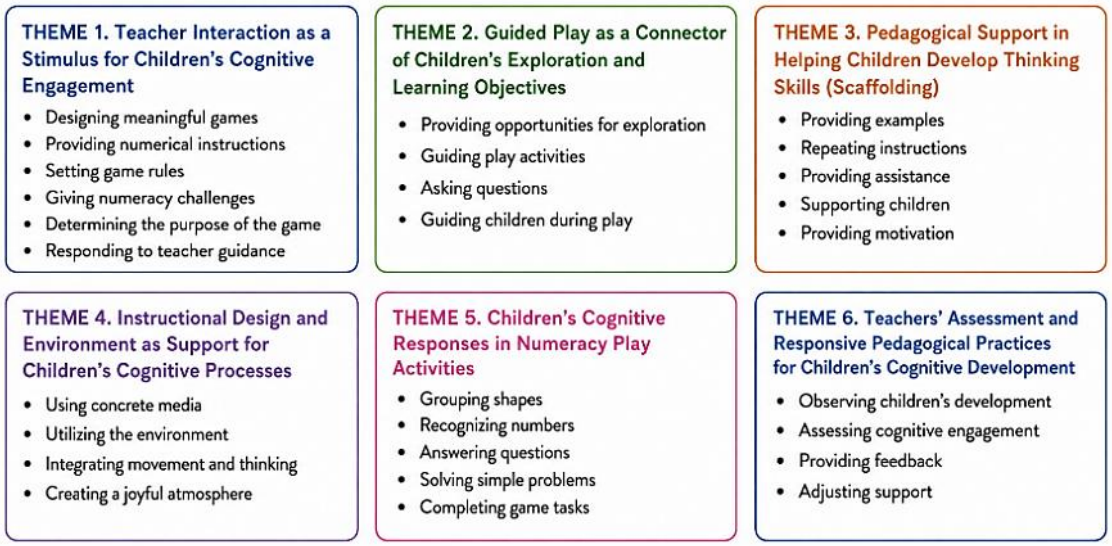

Figure 9. Development of Themes on the Relationship Between Children's Cognitive Processes and Teachers' Pedagogical Processes

Based on the themes illustrated in Figure 9, the main emerging theme is pedagogical interaction as a trigger for children's cognitive engagement. Observation results showed that play activities were always accompanied by instructions, guidance, and challenges that encouraged children to think and respond to play situations. In the activity of writing numbers after running toward the finish line, for example, the teacher not only involved physical activity but also provided numerical instructions that the children had to understand. Activities such as giving number instructions, responding to teacher guidance, and completing game tasks demonstrate the relationship between teachers' pedagogical stimulation and children's thinking processes.

The second theme is guided play as a bridge between children's exploration and learning objectives. Observation results showed that teachers provided children with opportunities to explore independently while still offering guidance and assistance during play activities. In geometric shape grouping activities, children were given the freedom to choose and classify shapes, while teachers provided questions and assistance when children experienced difficulties. Activities such as giving guidance, asking questions, and directing play activities were categorized as forms of guided play, while children's activities such as grouping shapes and making selections demonstrated children's cognitive engagement during the learning process.

The next theme is pedagogical support in assisting the development of children's thinking abilities. Teachers provided assistance through repeated instructions, demonstrations, and guidance for children who were not yet able to complete activities independently. Activities such as giving examples, repeating instructions, and accompanying children demonstrate forms of pedagogical scaffolding that helped children understand learning activities and complete the games.

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In addition, the analysis results showed that children's active engagement increased when teachers used contextual media and activities such as puzzles, blocks, geometric shapes, and outdoor games. The use of these media made children more active in responding to instructions and participating in learning activities, indicating a relationship between teachers' pedagogical design and the quality of children's cognitive engagement. The thematic relationships identified from this analysis are illustrated in Figure 10.

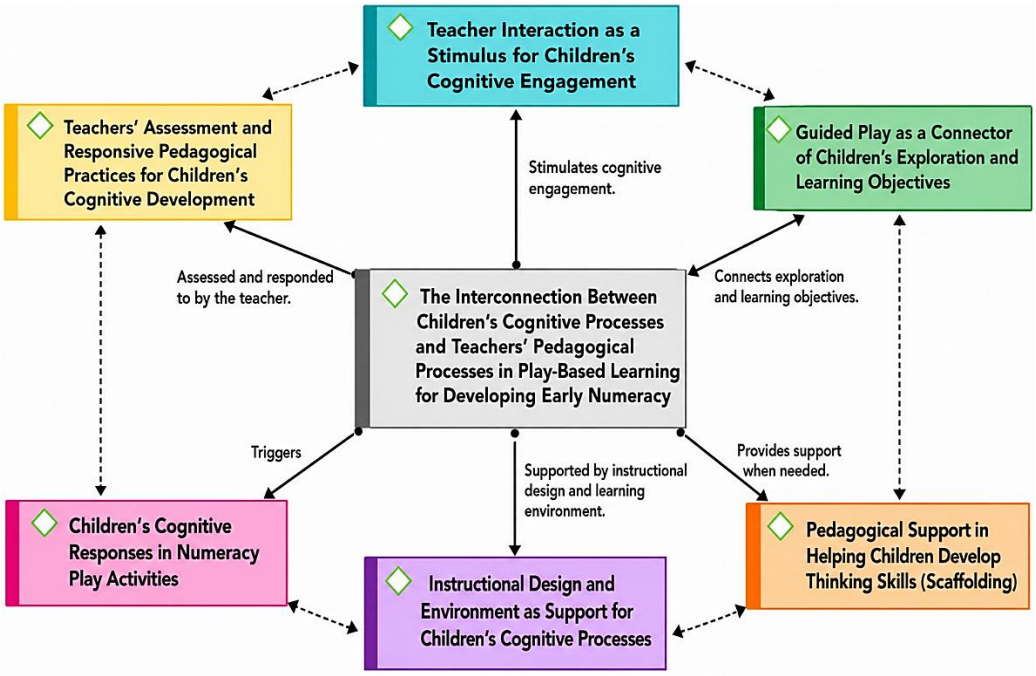

Figure 10. Theme Network of the Relationship Between Children's Cognitive Processes and Teachers' Pedagogical Processes

As presented in Figure 10, children's cognitive processes and teachers' pedagogical processes in play-based learning demonstrate a reciprocal relationship. Teachers provide pedagogical stimulation through guidance, questions, and learning support, while children respond through thinking activities, exploration, and simple problem-solving. These findings indicate that the development of children's early numeracy is influenced not only by individual abilities, but also by the quality of pedagogical interactions established during play-based learning.

Discussion

Play as a Cognitive Mechanism in Early Numeracy Development

The results of the study indicate that play-based learning plays an important role in supporting early numeracy development through children's engagement in exploratory, manipulative, and interactive activities. Activities such as recognizing numbers, grouping geometric shapes, assembling puzzles, and instruction-based games help children construct contextual and meaningful numeracy understanding. These findings confirm that early numeracy develops through thinking processes during play, rather than through memorization alone. Research by Musi & Sugiarti (2025) also shows that traditional games can improve early numeracy while simultaneously instilling Islamic values in early childhood.

From a cognitive perspective, play activities enable children to identify symbols, classify objects, make simple decisions, and solve basic problems. Children appeared actively engaged in responding to instructions, recognizing number symbols, and grouping objects based on certain characteristics. These findings are consistent with Vygotsky's social constructivist

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theory (Etnawati, 2021), which emphasizes that cognitive development evolves through social interaction and contextual learning experiences. This condition is also supported by Siswanto et al. (2025), who state that contextual learning helps children construct conceptual understanding more meaningfully.

The findings of this study strengthen the results of Skene et al. (2022), who found that guided play contributes positively to children's early mathematics development. The use of concrete media such as puzzles, blocks, and geometric shapes helps children understand numeracy concepts through manipulative and exploratory experiences, as explained by Cutting & Lowrie (2023). In addition, games involving motor activities such as running while writing numbers demonstrate the integration of physical activity and children's thinking processes, in line with the research of Jylänki et al. (2023).

This study also shows that play activities can develop logical thinking and simple problem-solving abilities when children follow game rules and determine answers, as explained by (Li & Disney, 2023). In addition to supporting cognitive development, play-based learning increases children's emotional engagement and learning motivation. Therefore, play can be understood as a cognitive mechanism that supports early numeracy development through active and meaningful learning experiences.

Guided Play and Teachers' Pedagogical Roles in Numeracy Learning

The results of the study indicate that teachers' pedagogical processes play an important role in supporting early numeracy development through play-based learning. Play activities at RA Jauharul Huda were designed and directed through instructions, the use of play media, activity organization, and guidance throughout the learning process. These findings demonstrate that the learning practices reflected the concept of guided play, an approach that integrates children's exploration with teachers' pedagogical guidance.

Teachers designed activities such as number-guessing games, geometric shape grouping, number-based motor games, and verbal games to stimulate children's numeracy abilities. Guided play practices were evident through the provision of instructions, guiding questions, and assistance when children experienced difficulties. These findings are consistent with Nopiana & Misgiyati (2025), who explain that guided play enables children to learn actively with teachers' pedagogical support.

The use of concrete media such as puzzles, blocks, and geometric shapes helped children understand numeracy concepts in a more concrete and interactive manner. These findings support the study of Saputra (2024), which states that play-based learning environments can improve children's engagement and mathematical thinking abilities. In addition, teachers also implemented scaffolding through repeated instructions, demonstrations, and assistance to children, in accordance with Vygotsky's Zone of Proximal Development theory (Xi & Lantolf, 2021).

The findings of this study indicate that enjoyable pedagogical approaches made children more active, enthusiastic, and responsive in numeracy learning. Therefore, the success of play-based learning is determined not only by the games used, but also by teachers' pedagogical abilities in designing and facilitating meaningful learning experiences for children.

Cognitive and Pedagogical Interaction as an Ecosystem of Early Numeracy Learning

The results of the study indicate that the development of early numeracy in play-based learning evolves through the interaction between children's cognitive processes and teachers' pedagogical processes. Play activities become a space for children to recognize numbers, group shapes, follow rules, and solve simple problems, while teachers provide instructions, questions, challenges, and assistance throughout the learning process. This condition demonstrates a

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reciprocal relationship between teachers' pedagogical stimulation and children's cognitive engagement.

Play-based learning encourages children to become more active in exploration and problem-solving compared to one-way formal instruction. These findings are consistent with Vygotsky's sociocultural theory (Etnawati, 2021), which emphasizes the importance of social interaction and pedagogical support in children's cognitive development. The use of concrete media such as puzzles, blocks, geometric shapes, and outdoor games also increased children's engagement in numeracy learning. This condition supports the view of Hirsh-Pasek et al. (2020) that effective play-based learning occurs through active interaction among children, teachers, and the learning environment.

In addition to supporting numeracy development, play activities also integrate children's cognitive, social, emotional, and motor aspects simultaneously. When children play while moving and interacting, they develop not only numeracy abilities, but also communication skills, self-regulation, and social cooperation. These findings are in line with the studies of Chen (2024) and Nurhidayati et al. (2026), which explain that play-based learning creates a learning ecosystem that supports multiple aspects of child development simultaneously. Therefore, play-based learning can be understood as a learning ecosystem that integrates children's cognitive processes, teachers' pedagogical support, and interactive learning environments in supporting early numeracy development.

4. CONCLUSION

This study demonstrates that play-based learning is a pedagogical approach capable of supporting early childhood numeracy development through active engagement, exploration, social interaction, and meaningful learning experiences. Children's cognitive processes develop through play activities that enable them to recognize numerical symbols, classify objects, solve simple problems, and develop logical thinking skills contextually.

This study also confirms that teachers' pedagogical processes play an important role in the success of play-based numeracy learning. Teachers are responsible for designing purposeful play activities, utilizing concrete media, and providing guidance and pedagogical support through guided play and scaffolding approaches. The interaction between children's cognitive processes and teachers' pedagogical processes becomes the main factor in creating effective and meaningful numeracy learning experiences.

Conceptually, this study strengthens the understanding that early numeracy development does not emerge solely through formal instructional learning, but through the integration of play experiences, pedagogical interactions, and contextual learning environments. Therefore, play-based learning can be understood as a pedagogical ecosystem that connects children's natural play activities with the development of numeracy abilities in a more holistic manner and in accordance with the developmental characteristics of early childhood.

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