The International Journal of
Emerging Issues in
Early Childhood Education
(IJEIECE)

Vol. 8 No. 1 (2026)
p-ISSN 2655-9986; e-ISSN 2685-4074
https://doi.org/ 10.33830/ijeiece.v8i1.13604

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Research Paper

Learning Through Exploration: How Maze-Based Activities Support Problem-Solving Development in Early Childhood

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Abstract

Developing problem-solving skills in early childhood is essential for supporting lifelong learning, yet many early learning environments still rely on passive and teacher-directed approaches that provide limited opportunities for active exploration and strategic thinking. This study examines the effectiveness and underlying mechanisms of exploratory maze-based learning in supporting problem-solving development in early childhood education. An evidence-informed mixed-methods design was employed, integrating a quantitative pre-experimental approach with a systematic literature review (SLR). The quantitative phase involved 54 children aged 5–6 years using a one-group pretest–post-test design to assess changes in four problem-solving dimensions: understanding the problem, planning strategies, executing solutions, and evaluating outcomes. The intervention consisted of physically embedded maze-based activities that promoted active exploration, decision-making, and iterative trial-and-error processes. The results reveal a substantial improvement in children's problem-solving performance, indicated by a marked increase in independent problem-solvers and a reduction in children requiring assistance or experiencing difficulties. Dimension-level analysis further shows notable gains in strategic planning, execution, and adaptive evaluation. The SLR findings explain these improvements through key cognitive and pedagogical mechanisms, including executive function activation, embodied learning, spatial reasoning, and guided scaffolding. By integrating empirical findings with synthesized evidence, this study provides a mechanism-based explanation of how exploratory learning environments facilitate early cognitive development. The findings highlight the importance of movement-based, spatially structured, and scaffolded learning experiences in fostering adaptive and independent problem-solving. This study contributes to the field by advancing a theoretically grounded and empirically supported model for designing innovative, play-based learning environments in early childhood education.

Keywords: *exploratory learning; maze-based learning; problem-solving; executive function; early childhood education*

To cite this article:
Andani, E. K. T., Rachmawati, Y., & Ayu, H. D. (2026). *Learning through exploration: How maze-based activities support problem-solving development in early childhood*. The International Journal of Emerging Issues in Early Childhood Education (IJEIECE), 8(1).
To link to this article: https://jurnal.ut.ac.id/index.php/ijeiece
Published by: Universitas Terbuka
Jl. Pd. Cabe Raya, Pd. Cabe Udik, Kec. Pamulang, Kota Tangerang Selatan, Banten 15437

INTRODUCTION

Early childhood education plays a pivotal role in shaping foundational cognitive capacities that underpin lifelong learning, adaptability, and academic success. Among these capacities, problem-solving skills are increasingly recognized as central to children's ability to interpret situations, generate alternative strategies, and make informed decisions in complex and dynamic environments. Contemporary research emphasizes that problem-solving in early childhood is not merely an outcome of biological maturation but is actively constructed through interactions with rich, stimulating environments that foster exploration, engagement, and meaning-making (Diamond & Ling, 2020; Muir et al., 2023; Gibb et al., 2021). From a developmental perspective, children's problem-solving abilities emerge through iterative processes of trial-and-error, reflection, and adaptation, which are strongly influenced by the quality of learning experiences provided in early educational settings (Weisberg et al., 2021; Toub et al., 2021). In this context, learning experiences that are hands-on, inquiry-driven, and play-based are particularly effective in fostering higher-order thinking, as they enable children to experiment, test ideas, and refine their understanding through meaningful and self-directed activity.

Exploratory learning, as a core dimension of play-based pedagogy, has gained increasing attention for its role in promoting cognitive flexibility, self-regulation, and executive function in young children. Executive function, encompassing working memory, inhibitory control, and cognitive flexibility, is strongly associated with early problem-solving development and long-term academic achievement (Diamond & Ling, 2020; Bustamante et al., 2022). Within exploratory learning environments, children are encouraged to navigate uncertainty, formulate hypotheses, and adjust their strategies based on feedback and environmental cues. Such processes are essential for developing adaptive thinking and metacognitive awareness. Among various exploratory learning activities, maze-based tasks represent a particularly promising yet underexplored pedagogical tool. These activities require children to analyse spatial configurations, anticipate possible pathways, and make sequential decisions, thereby integrating cognitive, motor, and perceptual processes in a unified learning experience. Empirical studies suggest that spatial navigation and embodied learning experiences, such as those involved in physical maze exploration, significantly enhance children's reasoning abilities, executive functioning, and problem-solving performance (Newcombe, 2020; Frick, 2021).

However, despite the strong theoretical and empirical support for play-based and exploratory learning, existing research has largely focused on static or screen-based maze activities, with limited attention given to physically embedded, exploratory maze experiences in authentic early childhood contexts. Moreover, prior studies tend to examine these interventions in isolation, lacking integrative frameworks that combine empirical findings with systematic evidence synthesis to explain the underlying cognitive and pedagogical mechanisms through which maze-based exploration enhances problem-solving skills. This fragmentation limits the ability to draw comprehensive conclusions about how exploratory learning environments can be optimally designed to support children's cognitive development (Zosh et al., 2022; Weisberg et al., 2021). Addressing this gap, the present study adopts an evidence-informed mixed-methods approach, integrating quantitative experimental data with insights derived from a systematic literature review to provide a more holistic understanding of how exploratory maze-based activities support problem-solving development in early childhood.

Building on this rationale, the study is guided by the following research questions, (1) How do exploratory maze-based activities influence the problem-solving abilities of young children in early childhood education settings? (2) To what extent do children's problem-solving skills improve after participating in exploratory maze-based learning activities? (3) Which specific aspects of problem-solving, such as understanding problems, planning strategies, decision-making, and evaluation, show the most significant development following the intervention? (4) How do findings from the systematic literature review explain the cognitive and learning mechanisms underlying the observed changes in children's problem-solving skills?

This study offers several important contributions to the field of early childhood education. First, it advances existing literature by examining exploratory, physically embedded maze-based learning, thereby moving beyond the dominant focus on static or digital maze activities. Second, it introduces an evidence-informed mixed-methods design that integrates experimental findings with systematic literature synthesis, enabling a more robust and theoretically grounded interpretation of learning outcomes. Third, the study bridges the gap between play-based pedagogy and executive function research, highlighting how embodied exploration within maze activities supports not only problem-solving skills but also broader cognitive processes essential for early learning and development. Through this integrative approach, the study contributes both empirically and conceptually to the design of innovative, developmentally appropriate learning environments in early childhood education.

LITERATURE REVIEW

Exploratory and Play-Based Learning in Early Childhood

Exploratory learning in early childhood is grounded in the view that children develop cognitive competence through active engagement with objects, spaces, peers, and meaningful challenges (Ernst et al., 2022). In this perspective, play is not merely recreational but functions as a pedagogical context in which children observe, test ideas, revise strategies, and construct understanding through direct experience (Hu et al., 2023). This is particularly important for problem-solving development because young children often learn to solve problems through embodied actions, repeated attempts, and environmental feedback (Berson et al., 2023). Evidence from nature-based preschool practices shows that learning environments rich in movement, exploration, and child autonomy can support executive function development, especially when children are given opportunities to interact actively with their surroundings rather than only receiving teacher-directed instruction (Ernst et al., 2022).

Exploratory maze-based activities are strongly aligned with this principle because they require children to move through space, identify obstacles, compare possible routes, and decide which pathway should be tried next. Unlike static worksheet-based mazes, physically embedded maze activities transform problem-solving into a lived learning experience. Children do not only think about a solution; they enact it through movement, observation, and strategy adjustment. Research on guided play with programmable robots similarly demonstrates that children's spatial and computational understanding develops through navigation, embodied reference, teacher scaffolding, and interaction with spatial pathways (Berson et al., 2023; Misirli & Komis, 2023).

Problem-Solving Development

Problem-solving in early childhood is closely related to executive function, particularly children's ability to focus attention, remember goals, inhibit impulsive responses, and shift strategies when an attempt does not work (Bai et al., 2022). In maze-based learning, these processes appear when children must remember the target destination, avoid repeating ineffective routes, regulate frustration when encountering a dead end, and select alternative paths. Therefore, maze play can be viewed as a cognitively demanding activity that naturally stimulates planning, working memory, inhibitory control, and cognitive flexibility.

Recent intervention research supports the relevance of play and movement for strengthening executive function in preschool children. Bai et al. (2022) found that an eight-week group-play physical activity intervention improved executive function and motor skills among 4- to 5-year-old preschoolers, suggesting that cognitively engaging movement-based play can support children's regulatory and thinking skills. In addition, Sukhikh et al. (2022) showed that role-play contexts involving adult support and meaningful emotional engagement may contribute to executive function development in early childhood. These findings strengthen the rationale for maze-based activities because exploratory maze play combines physical movement, cognitive challenge, emotional persistence, and teacher scaffolding within one learning experience.

Spatial Reasoning, Navigation, and Embodied Problem-Solving

Maze-based activities are especially relevant for early childhood problem-solving because they involve spatial reasoning. Children are required to understand direction, position, route, distance, and relational space while simultaneously making decisions. Spatial reasoning becomes visible when children choose a path, evaluate whether it leads to the goal, remember previously tried routes, and change direction when necessary. Thus, maze activities create a natural bridge between spatial cognition and problem-solving behavior (Presser et al., 2023).

Evidence from early childhood computational thinking research also supports this connection. Studies in *Early Childhood Research Quarterly* show that preschool learning activities involving navigation, digital tools, robotics, and teacher-guided spatial language can support children's spatial reasoning, computational thinking, and early problem-solving processes (Clarke-Midura et al., 2023). For example, Berson et al. (2023) found that guided play with a programmable robot helped preschoolers develop spatial concepts through body-based reference, verbal scaffolding, and path navigation. Similarly, studies in the same special issue report that data collection, formative assessment, teacher talk, and tangible robotics can create rich contexts for developing early computational and spatial thinking (Hu et al., 2023; Misirli & Komis, 2023).

Research Gap and Position of the Present Study

Although existing studies have examined play-based learning, executive function, spatial reasoning, and early computational thinking, fewer studies have directly investigated how physically embedded maze-based activities support problem-solving development in authentic early childhood classrooms. Much of the available literature focuses on nature play, role play, physical activity, robotics, or digital learning tools, while exploratory maze activities remain relatively underdeveloped as a specific pedagogical model (Ernst et al., 2022; Bai et al., 2022). This creates an important gap because maze-based learning uniquely combines spatial navigation, physical movement, trial-and-error, decision-making, and reflective strategy use.

Therefore, the present study positions exploratory maze-based learning as an innovative early childhood pedagogy that integrates play, movement, spatial reasoning, executive function, and problem-solving. Its contribution lies in examining maze activities not as simple games or worksheets, but as embodied exploratory experiences that allow children to understand problems, plan strategies, test alternatives, and evaluate outcomes through direct interaction with space and peers.

RESEARCH METHOD

Research Design

This study employed an evidence-informed mixed-methods design, specifically a sequential explanatory approach, in which quantitative data were collected and analyzed prior to qualitative interpretation (Creswell & Plano Clark, 2018). This design was selected to examine not only the effectiveness of exploratory maze-based activities on children's problem-solving skills but also to provide a theoretical explanation of the observed outcomes through a systematic literature review (SLR). The quantitative component focused on measuring changes in children's problem-solving abilities through an experimental approach, while the SLR component was used to synthesize prior empirical findings and explain the cognitive mechanisms underlying the results. The integration of both strands was conducted at the interpretation stage, following established mixed-methods procedures (Fetters et al., 2013).

To provide a clear overview of the research procedure, the study design is illustrated in Figure 1. The figure presents a sequential explanatory mixed-methods framework in which the quantitative phase is conducted first through an experimental approach, followed by a qualitative phase using a systematic literature review (SLR). The quantitative phase includes baseline observation, pretest, intervention through exploratory maze-based activities, posttest, and data analysis to examine changes in children's problem-solving skills. The results obtained from this phase subsequently inform the qualitative phase, where the SLR is conducted to identify and synthesize relevant theoretical and empirical evidence. Finally, both strands are integrated at the interpretation stage to explain the underlying mechanisms of learning and to provide a comprehensive understanding of how exploratory maze-based activities support problem-solving development in early childhood.

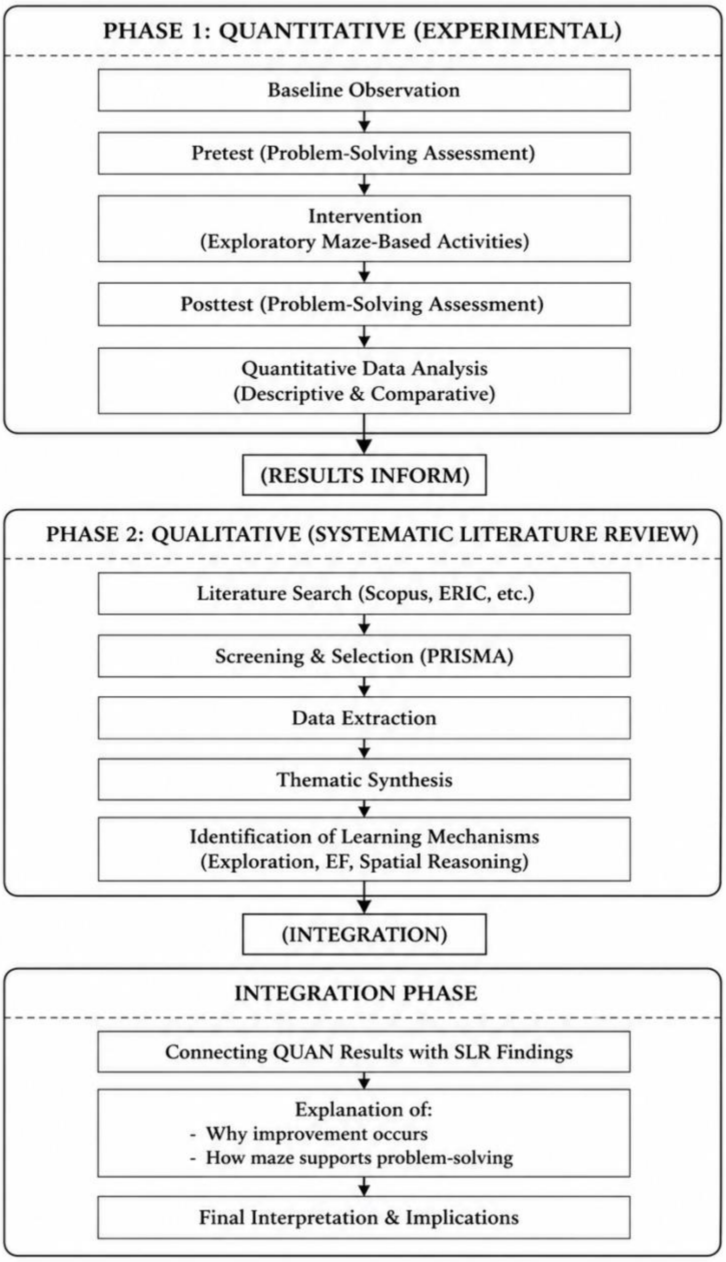

Figure 1. Evidence-Informed Mixed-Methods Design

Participants and Research Setting

The study was conducted in an early childhood education institution (TK Al Falah, Kota Batu, Indonesia). The participants consisted of 54 children aged 5–6 years (Group B), selected through purposive sampling based on their active participation in classroom learning. The research was implemented within a natural classroom setting to maintain ecological validity. Learning activities were integrated into regular instructional routines, particularly through play-based and exploratory approaches appropriate for early childhood development.

Quantitative Phase: Experimental Procedure

Quantitative Research Design

The quantitative phase adopted a pre-experimental one-group pretest–posttest design to evaluate the effectiveness of exploratory maze-based activities in improving children's problem-solving skills (Fraenkel et al., 2019).

Quantitative Procedure

The procedure of this study was conducted in three main stages: pretest, intervention, and posttest. In the first stage, the pretest (baseline assessment) was carried out to identify children's initial problem-solving abilities. This assessment was conducted through structured observation using predefined indicators, including children's ability to understand the problem, plan strategies, execute solutions, and evaluate outcomes. The pretest provided an initial profile of each child's problem-solving performance prior to the implementation of the intervention. The second stage involved the intervention, which consisted of physically embedded exploratory maze-based activities. These activities were specifically designed to promote active exploration, stimulate decision-making processes, encourage trial-and-error learning, and support peer interaction. During the implementation, children were given opportunities to navigate maze pathways, consider alternative routes, and make independent decisions while solving problems. Teachers functioned as facilitators rather than direct instructors, providing minimal guidance and encouraging children to reflect on their actions and strategies.

The final stage was the posttest, conducted after the intervention to assess changes in children's problem-solving abilities. The same observational instrument used in the pretest was employed to ensure consistency in measurement. The posttest results were then compared with the pretest data to identify improvements in children's ability to understand problems, plan and execute solutions, and evaluate outcomes following their participation in exploratory maze-based learning activities.

Instrument and Data Collection

To systematically assess children's problem-solving abilities, an observation-based instrument was developed based on key dimensions of early childhood problem-solving. The instrument focuses on four core components: understanding the problem, planning strategies, executing solutions, and evaluating outcomes. Each component is operationalized into observable behavioral indicators and assessed using a four-level developmental rating scale. The detailed structure of the instrument is presented in Table 1.

Table 1. Observation-Based Problem-Solving Indicators for Early Childhood

No	Dimension	Indicator	Behavioral Description
1	Understanding the Problem	Identifies task goal	Child recognizes the objective of the task
		Recognizes obstacles	Child identifies barriers or challenges in the task
2	Planning Strategies	Selects appropriate strategy	Child chooses a path or approach to solve the problem

		Predicts outcomes	Child anticipates possible results of chosen actions
3	Executing Solutions	Implements strategy	Child carries out the chosen approach
		Adjusts strategy	Child modifies actions when encountering difficulty
4	Evaluating Outcomes	Reflects on result	Child reviews whether the solution works
		Explains reasoning	Child explains the solution or decision taken

Quantitative Data Analysis

Quantitative data were analyzed using both descriptive and comparative statistical techniques. Descriptive statistics, including frequency, percentage, and mean scores, were employed to provide an overview of children's problem-solving performance in both the pretest and posttest phases. These measures allowed for the identification of general patterns and distributions of children's abilities across different levels of performance.

In addition, a comparative analysis was conducted to examine differences between pretest and posttest scores. This analysis aimed to determine the extent to which children's problem-solving abilities improved following the implementation of exploratory maze-based activities. The comparison focused not only on overall performance but also on specific dimensions of problem-solving, including understanding the problem, planning strategies, executing solutions, and evaluating outcomes. Through this approach, the analysis provided a detailed understanding of both general improvement and dimension-specific changes in children's problem-solving development.

Qualitative Phase: Systematic Literature Review (SLR)

Search Strategy

The literature search was conducted systematically using several major academic databases to ensure comprehensive coverage of relevant studies. The databases included Scopus, ScienceDirect, ERIC, and Google Scholar, which were selected due to their extensive indexing of peer-reviewed journals in the fields of education, psychology, and early childhood development.

The search process employed a set of predefined keywords reflecting the main constructs of the study, including *exploratory learning*, *maze-based learning*, *problem solving in early childhood*, and *executive function in preschool children*. These keywords were combined using Boolean operators such as AND and OR to refine the search results and ensure both breadth and specificity. The use of Boolean logic enabled the identification of studies that addressed the intersection between exploratory learning, cognitive development, and problem-solving processes in early childhood contexts.

Table 2. Literature Search Strategy

Component	**Description**
Databases	Scopus; ScienceDirect; ERIC; Google Scholar
Keywords	"exploratory learning"; "maze-based learning"; "problem solving early childhood"; "executive function preschool"
Search Technique	Combination of keywords using Boolean operators (AND, OR)
Example Search String	("exploratory learning" AND "problem solving") OR ("maze-based learning" AND "early childhood") OR ("executive function" AND "preschool")
Purpose	To identify relevant empirical and theoretical studies related to exploratory learning, problem-solving, and executive function in early childhood

This structured search strategy ensured that the selected studies were relevant to the research focus while maintaining a balance between inclusiveness and specificity. By combining multiple databases and carefully constructed keyword strings, the review process was able to capture a broad yet focused body of literature to support the interpretation of the study findings.

Inclusion and Exclusion Criteria

To ensure the rigor, relevance, and consistency of the systematic literature review, a set of predefined inclusion and exclusion criteria was established prior to the study selection process. These criteria were designed to identify studies that are directly aligned with the research objectives, particularly those examining exploratory learning, problem-solving, executive function, and spatial reasoning in early childhood contexts. The inclusion criteria focused on selecting recent, high-quality studies published in reputable international journals, while the exclusion criteria were applied to filter out studies that were not relevant, lacked methodological rigor, or did not match the targeted population and research scope. This systematic approach ensured that the selected literature provided a strong empirical and theoretical foundation for interpreting the findings of the present study.

The detailed inclusion and exclusion criteria used in the literature selection process are presented in Table 3. The table outlines the specific parameters applied to determine the eligibility of studies, including publication characteristics, research focus, population, and methodological considerations.

Table 3. Inclusion and Exclusion Criteria

Criteria	Inclusion Criteria	Exclusion Criteria
Publication Year	Studies published between 2020–2025	Studies published before 2020
Source Type	Peer-reviewed journal articles (Scopus-indexed or reputable international journals)	Non-peer-reviewed sources (theses, dissertations, blogs, reports)
Language	Articles published in English	Articles in other languages without reliable translation
Population	Early childhood (ages 3–6 years)	Studies focusing on primary, secondary, or adult populations
Research Focus	Studies addressing exploratory learning, problem-solving, executive function, or spatial reasoning	Studies unrelated to cognitive development or learning processes
Methodology	Empirical studies (quantitative, qualitative, or mixed methods) and systematic reviews	Opinion papers, editorials, or studies lacking clear methodology
Context	Educational or learning environments (formal or informal)	Non-educational contexts

The application of the inclusion and exclusion criteria presented in Table 3 ensured that only relevant and high-quality studies were included in the review. By systematically filtering studies based on clearly defined parameters, the selection process minimized potential bias and enhanced the validity of the literature synthesis. Furthermore, these criteria allowed the review to remain focused on studies that are directly related to early childhood learning processes, thereby strengthening the theoretical and empirical basis for interpreting the findings of the present research.

Data Extraction and Synthesis

Selected studies were systematically analyzed using a thematic synthesis approach to identify key patterns and concepts relevant to the focus of this research. The synthesis process aimed to extract and organize evidence related to learning mechanisms in exploratory environments, cognitive processes involved in problem-solving, and the role of spatial and embodied learning in early childhood contexts. Through this approach, recurring themes and relationships across studies were identified, allowing for a deeper understanding of how exploratory learning contributes to children's cognitive development.

The results of the thematic synthesis were subsequently used to interpret the findings obtained from the quantitative phase. In particular, the identified themes provided a theoretical basis for explaining changes in children's problem-solving abilities following the implementation of exploratory maze-based activities. This integrative process followed established literature review procedures to ensure systematic analysis and coherent interpretation of findings (Snyder, 2019).

Integration of Findings

The integration of findings was conducted at the interpretation stage, where the results obtained from the quantitative phase were systematically explained using insights derived from the systematic literature review (SLR). This integrative approach enabled the study to move beyond mere statistical comparison by providing a deeper, evidence-based understanding of the observed changes in children's problem-solving abilities.

Through this process, the empirical findings were connected with relevant theoretical perspectives, allowing for a more comprehensive interpretation of how exploratory maze-based activities influence learning outcomes. In addition, the integration facilitated the identification of underlying learning mechanisms, particularly those related to exploratory behavior, executive function, and spatial reasoning. By combining empirical data with synthesized literature evidence, the study was able to strengthen the validity and credibility of its conclusions, ensuring that the findings were both contextually grounded and theoretically supported.

Ethical Considerations

This study adhered to ethical standards in conducting research involving young children. All research activities were implemented within regular classroom practices to ensure that the learning process remained natural and did not disrupt the children's routine educational experiences. The intervention was designed as part of play-based learning activities, thereby maintaining a developmentally appropriate and child-friendly environment. Furthermore, no harmful or intrusive procedures were applied throughout the study. The activities were carefully structured to support children's engagement, well-being, and comfort, ensuring that participation did not cause any physical or psychological distress. Children's participation in the study followed institutional guidelines, and all procedures were conducted in accordance with ethical principles for research in early childhood education. This approach ensured that the rights, safety, and well-being of the participants were fully respected throughout the research process.

RESULTS AND DISCUSSION

Quantitative Result

The quantitative findings of this study describe changes in children's problem-solving abilities before and after the implementation of exploratory maze-based learning activities.

Pretest Results (Baseline Condition)

The initial assessment indicated that children's problem-solving abilities were still varied. Out of 54 children, 14 children (25.93%) were able to complete tasks and find solutions independently. Meanwhile, 19 children (35.19%) were able to complete tasks but still required teacher assistance, and 21 children (38.89%) experienced difficulties in determining problem-solving strategies and tended to depend on teacher guidance. These findings suggest that a considerable proportion of children had not yet developed independent problem-solving skills, particularly in terms of understanding the problem, planning strategies, and executing solutions.

To provide a clearer overview of changes in children's problem-solving performance, the distribution of participants across different ability categories before and after the intervention is presented in Table 4. The table summarizes the number of children classified as independent, requiring assistance, and experiencing difficulties during both the pretest and posttest phases. This comparison allows for the identification of shifts in performance levels and provides an initial indication of the effectiveness of exploratory maze-based learning activities in supporting the development of children's problem-solving skills.

Table 4. Pretest and Post-test

Category	Pretest (n)	Posttest (n)
Independent	14	30
With Assistance	19	15
Difficulties	21	9

Table 4 presents the distribution of children's problem-solving performance across three categories, independent, with assistance, and difficulties, before and after the intervention. The results indicate a clear and positive shift in children's problem-solving abilities following the implementation of exploratory maze-based learning activities. Prior to the intervention, only 14 children demonstrated the ability to solve problems independently. This number increased substantially to 30 children in the post-test, indicating a strong improvement in children's autonomy in problem-solving. This suggests that the intervention effectively supported children in developing the ability to understand problems, plan strategies, and execute solutions without relying on external assistance. In contrast, the number of children who required assistance decreased from 19 to 15. Although this category did not decline as sharply as the "difficulties" group, the reduction still indicates a transition of some children toward more independent problem-solving performance. This shift reflects gradual development, where children begin to rely less on teacher guidance and become more confident in applying their own strategies.

The most notable change was observed in the "difficulties" category, which decreased significantly from 21 children to only 9 children after the intervention. This reduction suggests that the exploratory maze-based activities were particularly effective in supporting children who initially struggled with problem-solving. The activities provided opportunities for repeated practice, trial-and-error learning, and experiential engagement, which helped children overcome initial challenges. Overall, the results demonstrate a meaningful redistribution of children across performance levels, with a clear movement from lower to higher levels of problem-solving ability. These findings indicate that exploratory maze-based learning not only improves overall performance but also supports developmental progression toward independent and adaptive problem-solving in early childhood.

To visually illustrate the changes in children's problem-solving performance before and after the intervention, a comparison between pretest and posttest results is presented in Figure 2. The figure displays the distribution of children across three categories, independent, with assistance, and difficulties, highlighting the shift in performance levels following the implementation of exploratory maze-based learning activities. This visual representation complements the tabular data by providing a clearer depiction of the increase in independent problem-solving and the corresponding decrease in reliance on assistance and experienced difficulties among children.

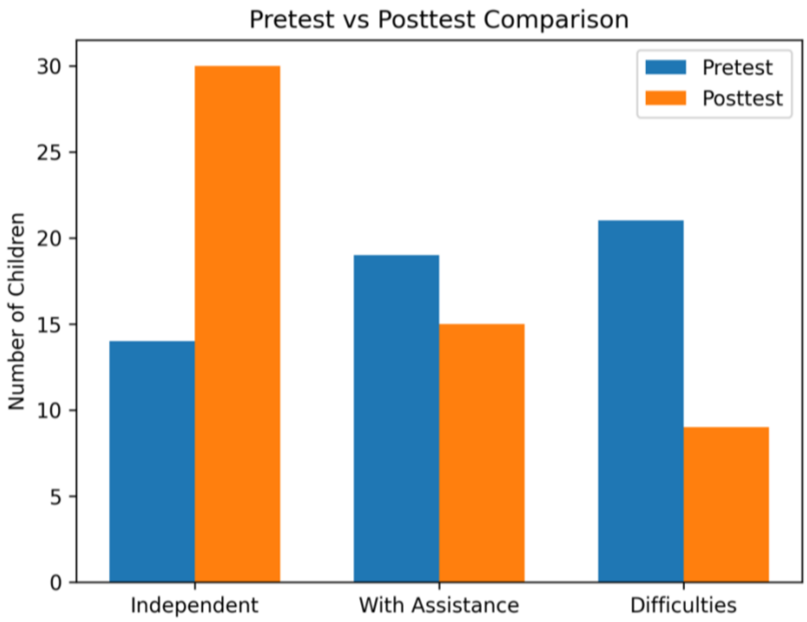

Figure 2. Pretest and posttest comparison of children's problem-solving performance across independent, with assistance, and difficulties categories.

In Figure 2, a comparison between pretest and post-test results shows a significant shift in the distribution of children's problem-solving abilities. The percentage of children categorized as independent increased substantially, while the proportions of children requiring assistance and experiencing difficulties decreased. Specifically, the independent category showed a positive gain, indicating that more children were able to solve problems autonomously after the intervention. In contrast, the "with assistance" and "difficulties" categories exhibited negative gain values, reflecting a reduction in dependency on teacher support and a decline in problem-solving challenges. These changes suggest that exploratory maze-based activities effectively facilitated the development of children's independence, strategic thinking, and adaptability in problem-solving.

Changes Across Problem-Solving Dimensions

Further analysis across the dimensions of problem-solving revealed notable improvements in several key areas of children's cognitive performance. In terms of understanding the problem, children showed increased ability to identify task goals and recognize obstacles within the given activities. This indicates a growing awareness of problem structure and task requirements. In the dimension of planning strategies, children demonstrated enhanced capacity to select appropriate approaches and anticipate possible solutions. This suggests that they were not only responding to tasks but also beginning to think ahead and organize their actions more systematically.

Improvements were also evident in executing solutions, where children displayed greater confidence and independence in implementing their chosen strategies. They were more willing to attempt solutions and persist in completing tasks, reflecting increased self-efficacy in problem-solving situations. Finally, in evaluating outcomes, children began to reflect on their actions and consider whether their chosen strategies were effective. They also showed an emerging ability to adjust their approaches when encountering difficulties, indicating the development of adaptive thinking and cognitive flexibility. Overall, these findings suggest that the intervention did not merely enhance children's overall problem-solving performance, but also contributed to the development of specific cognitive processes underlying effective problem-solving, including comprehension, planning, execution, and evaluation.

Qualitative Findings

Based on the PRISMA flow diagram, the literature search initially identified 1,087 records from four databases: Scopus, ScienceDirect, ERIC, and Google Scholar. After removing 215 duplicate records, 872 articles were screened by title and abstract. A total of 691 records were excluded because they were not directly related to problem-solving, play-based or exploration-based learning, maze-related activities, or early childhood education contexts. Subsequently, 181 full-text articles were assessed for eligibility, and 143 articles were excluded due to population mismatch, irrelevant interventions, or insufficient discussion of problem-solving outcomes. Finally, 38 studies were included in the synthesis.

To ensure transparency and rigor in the study selection process, a systematic literature review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The overall process of identifying, screening, assessing, and selecting relevant studies is illustrated in Figure 3. The diagram provides a structured overview of the number of records retrieved from multiple databases, the removal of duplicate entries, the screening of titles and abstracts, and the eligibility assessment of full-text articles. It also presents the reasons for exclusion at each stage, leading to the final set of studies included in the synthesis. This systematic procedure ensures that the selected literature is relevant, methodologically sound, and aligned with the objectives of the present study.

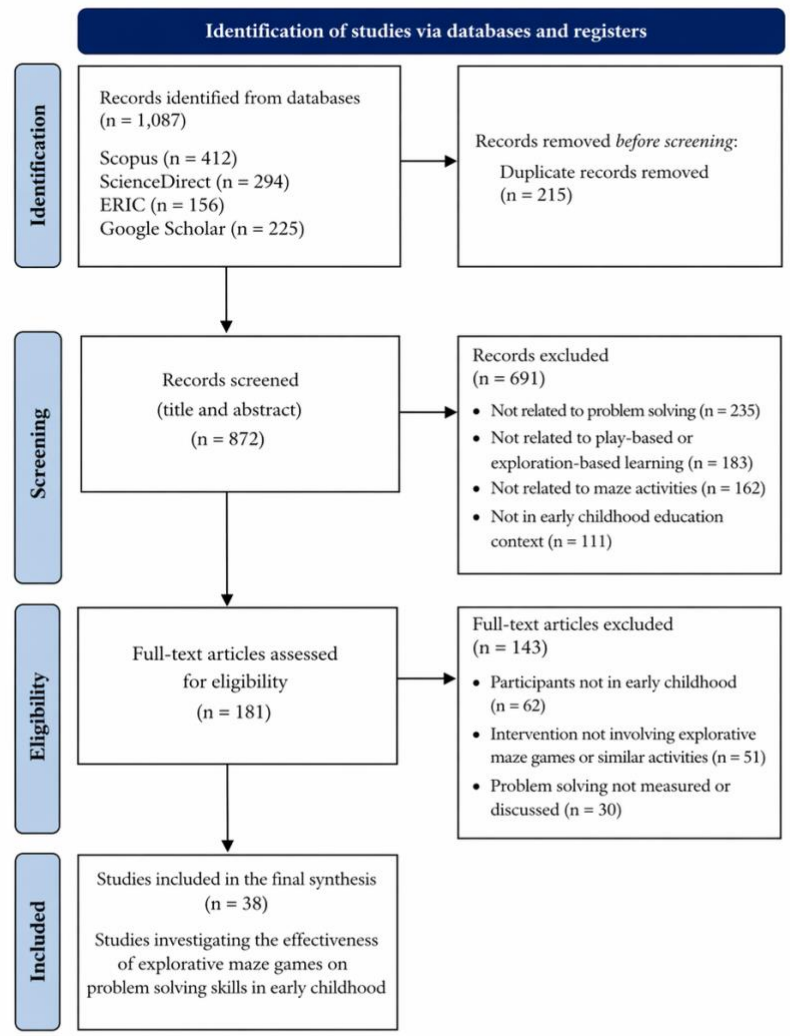

Figure 3. PRISMA Flow Diagram of the Literature Selection Process

The thematic synthesis of the selected literature revealed three major themes: exploratory and embodied learning, executive function and self-regulation, and spatial reasoning as a foundation for problem-solving. These themes explain how exploratory maze-based activities may support children's ability to understand problems, plan strategies, test alternative routes, and evaluate outcomes. To provide a focused synthesis of the most relevant evidence identified through the systematic literature review, Table 5 presents a summary of eight key studies that directly support the conceptual framework of this research. These studies were selected based on their alignment with the core constructs of exploratory learning, executive function, spatial reasoning, and problem-solving in early childhood contexts. The table outlines each study's focus, key findings, and its relevance to exploratory maze-based learning. By organizing the literature in this structured format, Table 5 highlights how prior empirical evidence consistently supports the role of exploration, movement-based learning, teacher scaffolding, and spatial navigation in enhancing children's cognitive and problem-solving abilities. This synthesis serves as a critical foundation for interpreting the quantitative findings and strengthens the theoretical grounding of the present study.

Table 5. Synthesis of Eight Supporting Studies from the SLR

No.	Author(s)	Key Findings	Relevance to Exploratory Maze-Based Learning
1	Ernst et al. (2022)	Nature-rich and exploration-based learning environments can support working memory, cognitive flexibility, and inhibitory control.	Supports the argument that exploratory environments help children regulate attention and adapt strategies during maze activities.
2	Bai et al. (2022)	Group-play physical activity improved executive function and motor skills among 4–5-year-old children.	Shows that movement-based play can stimulate cognitive control processes needed in maze navigation.
3	Sukhikh et al. (2022)	Role-play with adult involvement contributed to executive function development in early childhood.	Reinforces the importance of teacher scaffolding and guided reflection during exploratory maze play.
4	Berson et al. (2023)	Guided play with programmable robots supported spatial reasoning and computational thinking in preschoolers.	Strongly supports maze-based learning because both involve path navigation, direction, and spatial decision-making.
5	Clarke-Midura et al. (2023)	Early computational thinking can be assessed through children's problem-solving processes and strategy use.	Supports the use of observation rubrics to assess problem-solving dimensions during maze activities.
6	Hu et al. (2023)	Teacher scaffolding and technology-mediated classroom talk supported children's computational thinking processes.	Relevant to how teachers facilitate rather than directly instruct children during maze exploration.
7	Lewis Presser et al. (2023)	Preschoolers can engage in data-based reasoning and early computational thinking through meaningful activities.	Supports the idea that young children can process information, compare alternatives, and make decisions during maze tasks.
8	Misirli and Komis (2023)	Tangible robot programming improved young children's debugging knowledge and problem-solving strategies.	Closely related to maze play because children must identify errors, revise routes, and try alternative solutions.

Narrative Synthesis

The first major theme emerging from the SLR is that exploratory and embodied learning environments provide meaningful conditions for early problem-solving development. Ernst et al. (2022) showed that nature-based and exploration-rich environments can support executive function, especially working memory, cognitive flexibility, and inhibitory control. This finding is relevant to exploratory maze-based learning because children must remember goals, regulate impulses, and flexibly adjust routes when encountering dead ends. Similarly, Bai et al. (2022) demonstrated that group-play physical activity improved executive function and motor skills among preschoolers, indicating that physically active play can support children's cognitive regulation.

The second theme concerns the role of teacher scaffolding and guided participation. Sukhikh et al. (2022) found that role-play contexts involving adult support contributed to executive function development in early childhood. In exploratory maze-based activities, this implies that teachers should not dominate the task but should provide prompts, questions, and reflective support that encourage children to think independently. Hu et al. (2023) similarly emphasized that teacher talk can scaffold children's computational thinking in technology-mediated learning contexts. This supports the methodological choice in the present study, where teachers acted as facilitators rather than direct instructors.

The third theme highlights the connection between spatial reasoning, navigation, and problem-solving. Berson et al. (2023) found that guided play with programmable robots helped preschoolers develop spatial reasoning and computational thinking through path navigation. This is highly relevant to maze-based activities because children are required to recognize routes, compare pathways, make directional decisions, and revise strategies. Misirli and Komis (2023) also showed that tangible robot programming supported children's debugging knowledge, which parallels the trial-and-error processes used in maze exploration when children encounter incorrect routes and must find alternatives.

The fourth theme relates to assessment and observable problem-solving processes. Clarke-Midura et al. (2023) demonstrated that early computational thinking can be assessed through formative tasks that capture children's strategy use, reasoning, and problem-solving processes. Lewis Presser et al. (2023) further showed that preschoolers can engage in data collection, comparison, and analysis when learning activities are designed in developmentally appropriate ways. These findings support the use of observation-based indicators in the present study, particularly dimensions such as understanding problems, planning strategies, executing solutions, and evaluating outcomes.

Overall, the qualitative synthesis indicates that exploratory maze-based learning is supported by converging evidence from studies on executive function, embodied play, spatial reasoning, computational thinking, and teacher scaffolding. The SLR findings explain why maze-based activities can improve children's problem-solving: they require children to engage in active exploration, remember goals, control impulses, make spatial decisions, test alternatives, and revise strategies. Therefore, the qualitative findings strengthen the interpretation of the quantitative results by showing that improvement in children's problem-solving abilities is theoretically and empirically grounded.

Summary of SLR Findings and Their Contribution to Quantitative Results

To further integrate the qualitative findings with the quantitative results, Table 6 presents a summary of the key themes identified from the systematic literature review and their contribution to the observed changes in children's problem-solving abilities. The table highlights how theoretical and empirical evidence from previous studies supports and explains the improvements identified in the experimental phase.

Table 6. Summary of SLR Findings and Their Contribution to Quantitative Results

No.	Thematic Findings from SLR	Key Insight from Literature	Contribution to Quantitative Findings
1	Exploratory and active learning enhances problem-solving	Exploration-rich and movement-based environments support cognitive engagement and self-regulation	Explains the increase in children categorized as independent after the intervention
2	Executive function supports strategic thinking and self-regulation	Working memory, cognitive flexibility, and inhibitory control are essential for problem-solving	Supports improvement in planning strategies and reduced dependency on assistance
3	Teacher scaffolding facilitates gradual independence	Guided interaction helps children transition from supported to independent learning	Explains the decrease in “with assistance” category in posttest results
4	Spatial reasoning underpins navigation and decision-making	Navigation-based tasks improve spatial awareness and problem-solving strategies	Explains children’s improved ability to select and adjust solution pathways
5	Embodied learning strengthens cognitive processing	Physical engagement supports deeper learning and persistence	Explains reduction in “difficulties” category after intervention
6	Trial-and-error learning supports adaptive problem-solving	Debugging and revising strategies improve problem-solving flexibility	Supports improvement in executing and adjusting strategies
7	Early computational thinking relates to structured problem-solving	Children can analyze, compare, and select solutions through guided tasks	Explains improvements across all problem-solving dimensions
8	Meaningful learning contexts improve engagement and persistence	Contextual and meaningful activities increase motivation and focus	Supports overall improvement in children’s problem-solving performance

Integration of Findings

The integration of findings was conducted at the interpretation stage by systematically connecting the quantitative results with the evidence synthesized from the systematic literature review (SLR). This integrative approach allowed the study to move beyond descriptive analysis and provide an explanatory understanding of how exploratory maze-based activities support children’s problem-solving development. The quantitative findings demonstrated a clear shift in children’s problem-solving performance, particularly reflected in the increased number of children categorized as independent, alongside a reduction in those requiring assistance and experiencing difficulties. When interpreted in light of the SLR findings, these changes can be explained through several interconnected learning mechanisms. As summarized in Table 6, exploratory and movement-based learning environments have been shown to enhance cognitive engagement and self-regulation, which directly contribute to children’s ability to independently solve problems.

Furthermore, improvements observed in specific problem-solving dimensions, such as understanding the problem, planning strategies, executing solutions, and evaluating outcomes, are strongly supported by evidence on the role of executive function. The SLR findings indicate that working memory, cognitive flexibility, and inhibitory control play a critical role in enabling children to plan, adapt, and persist in problem-solving tasks. These cognitive processes are actively engaged during exploratory maze activities, where children must remember goals, navigate obstacles, and revise strategies when encountering dead ends.

The reduction in children’s reliance on teacher assistance can also be explained through the concept of guided learning and scaffolding. The SLR evidence highlights that teacher facilitation, through prompts, questioning, and reflective support, enables children to gradually transition from supported to independent problem-solving. This aligns with the instructional approach applied in the intervention, where teachers acted as facilitators rather than direct instructors, allowing children to construct their own understanding through exploration. In addition, the role of spatial reasoning and embodied learning provides a strong explanation for the observed improvements in strategy execution and adaptability.

The SLR findings suggest that navigation-based and movement-oriented activities enhance children’s ability to make spatial decisions, compare alternative routes, and adjust their actions based on feedback. These processes are central to maze-based learning, where children physically and cognitively engage with problem-solving tasks. Overall, the integration of quantitative and qualitative findings demonstrates that the effectiveness of exploratory maze-based learning is not only evidenced by improved performance outcomes but also supported by well-established theoretical and empirical foundations. The alignment between empirical data and literature evidence strengthens the validity of the study and confirms that problem-solving development in early childhood can be effectively supported through learning environments that combine exploration, movement, spatial reasoning, and guided facilitation.

Figure 4 presents a mechanism-based explanatory model integrating quantitative findings and evidence from the systematic literature review (SLR) to explain children’s problem-solving development. The model illustrates how improvements observed in the quantitative phase are theoretically grounded in executive function, embodied learning, and guided play, which activate core mechanisms such as cognitive flexibility, working memory, and exploration dynamics.

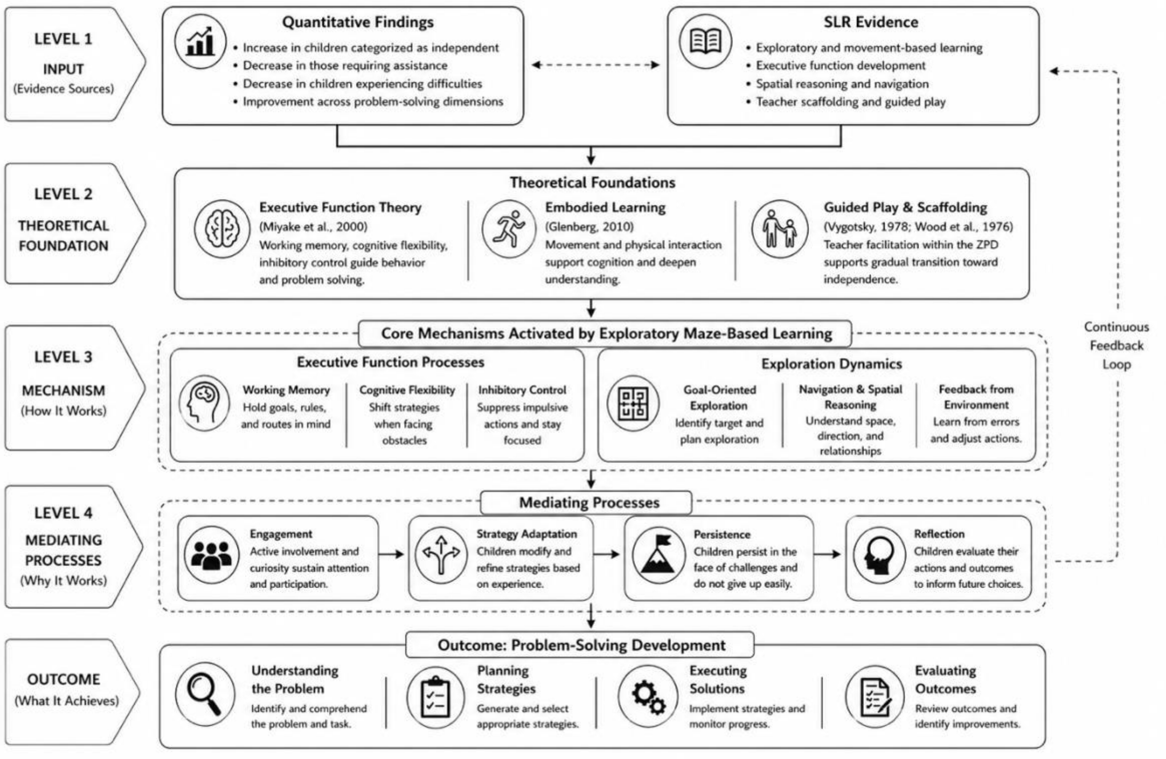

Figure 4. Integration of Quantitative Findings and SLR Evidence in Explaining Problem-Solving Development

Overall, the model presented in Figure X demonstrates how the integration of empirical findings and theoretical evidence provides a coherent explanation of the processes underlying children's problem-solving development. Rather than viewing learning outcomes as isolated results, the model emphasizes the dynamic interplay between cognitive mechanisms, experiential learning processes, and guided facilitation.

The presence of a continuous feedback loop further highlights the iterative nature of learning, where children refine their strategies through repeated exploration and reflection. This integrative perspective strengthens the validity of the study by showing that improvements in problem-solving are not incidental, but are systematically supported by well-established theoretical and empirical foundations. Consequently, the model offers a robust framework for understanding and designing exploratory learning environments that effectively foster cognitive development in early childhood education.

Discussion

RQ1. How do exploratory maze-based activities influence the problem-solving abilities of young children in early childhood education settings?

The findings indicate that exploratory maze-based activities influenced children's problem-solving abilities by creating a learning environment that required active exploration, decision-making, and adaptive strategy use. Children were not merely completing a task; they were required to observe pathways, identify obstacles, select possible routes, and revise decisions when their initial strategies did not work. This aligns with recent evidence that young children's problem-solving is strengthened when learning tasks are situated in meaningful, playful, and cognitively engaging contexts (Doebel, 2020; Moreno-Llanos et al., 2024; Yusumut, 2026; Burns et al., 2025). In this study, the maze activity functioned as an embodied problem-solving context because children used physical movement, spatial judgment, attention control, and trial-and-error processes simultaneously.

The results also suggest that exploratory maze-based activities promoted children's autonomy. The increase in children categorized as independent indicates that the intervention helped children move from passive reliance on teacher support toward more self-directed problem-solving. This finding is consistent with recent studies showing that play-based, movement-based, and guided learning experiences can support children's executive function, particularly inhibitory control, working memory, and cognitive flexibility (Lambert et al., 2025; Zhao et al., 2026; Yaffe et al., 2025; Wang et al., 2025). In maze learning, these processes are activated when children remember goals, inhibit impulsive choices, shift routes, and persist after encountering dead ends.

RQ2. To what extent do children's problem-solving skills improve after participating in exploratory maze-based learning activities?

The quantitative findings show a meaningful shift in children's problem-solving performance after the intervention. The number of children categorized as independent increased from 14 to 30, while the number of children requiring assistance decreased from 19 to 15, and those experiencing difficulties decreased from 21 to 9. This redistribution indicates that exploratory maze-based activities were associated with substantial improvement in children's problem-solving independence. This improvement can be interpreted as both a performance gain and a developmental shift. Children who initially struggled appeared to benefit from repeated opportunities to test strategies, receive environmental feedback, and adjust their actions. This pattern is consistent with studies indicating that repeated engagement in play-based and physically active tasks can strengthen executive function and self-regulation in preschool children (Chen et al., 2025; Lu et al., 2025; Cai et al., 2025; Ruffini et al., 2025). Moreover, the decrease in the "difficulties" category suggests that maze-based learning may be particularly beneficial for children who initially show lower levels of confidence, persistence, or strategy use.

The findings also support the view that early cognitive development is sensitive to the quality and structure of learning experiences. Research on preschool duration, classroom stimulation, and executive function indicates that children's cognitive control and learning readiness can improve when they are placed in environments that provide challenge, interaction, and guided participation (Gavrilova et al., 2024; Kvintová et al., 2025; Madanipour et al., 2025). Thus, the observed improvement in this study is not only a result of exposure to a game but also reflects the value of structured exploratory learning.

RQ3. Which specific aspects of problem-solving show the most significant development following the intervention?

The most visible development appeared in children's independence in executing solutions and adapting strategies. Children became more capable of identifying goals, selecting pathways, trying alternative routes, and evaluating outcomes. These changes reflect improvement across four problem-solving dimensions: understanding the problem, planning strategies, executing solutions, and evaluating outcomes. The dimension of planning strategies is particularly important because maze-based activities require children to anticipate possible routes before acting. This aligns with evidence that spatial reasoning contributes to children's capacity to organize information, compare alternatives, and solve problems in structured tasks (Poltz et al., 2026; Harris et al., 2025; Bobrowicz & Mendes, 2026; Mulligan, 2025). In this study, children's improved ability to choose routes and revise decisions suggests that spatial navigation helped stimulate planning and flexible thinking.

Decision-making and evaluation also improved because the maze required children to recognize whether a selected path led to success or failure. This process resembles debugging, design thinking, and early computational reasoning, in which learners identify errors, revise plans, and test alternative solutions (Badr et al., 2025; Critten et al., 2025; Zviel-Girshin, 2025; Grönman et al., 2025). Therefore, maze-based learning can be understood as a developmentally appropriate problem-solving task that allows children to experience "mistake-based learning" in a safe and playful environment.

RQ4. How do SLR findings explain the cognitive and learning mechanisms underlying the observed changes?

The SLR findings explain the observed quantitative improvement through four interconnected mechanisms: executive function activation, embodied exploration, guided scaffolding, and reflective strategy adaptation. First, executive function supports children's ability to regulate attention, hold goals in mind, inhibit impulsive responses, and shift strategies. These mechanisms are central to problem-solving and are repeatedly identified in recent research on preschool cognition and learning (Doebel, 2020; Veraksa et al., 2024; Li et al., 2024; Özsoy, 2025). During maze activities, children had to remember the destination, avoid ineffective routes, and adjust plans when they encountered obstacles. Second, embodied exploration explains why physical maze activities may be more powerful than static worksheet tasks. Children's movement through space provides immediate sensory and environmental feedback, enabling them to connect action with outcome. Recent studies on spatial thinking, movement, and play show that children's cognitive development is strengthened when learning involves active bodily engagement and spatial reasoning (Zhao et al., 2026; Chen et al., 2025; Harris et al., 2025; Bobrowicz & Mendes, 2026). Thus, the maze functioned not only as a game but also as an embodied learning environment. Third, the reduction in teacher assistance can be explained by guided play and scaffolding. Teacher facilitation through prompts and reflective questioning supports children's gradual transition from assisted to independent problem-solving. Recent studies on guided play, play-responsive pedagogy, and early childhood digital or scientific learning contexts emphasize that adult support is most effective when it sustains children's agency rather than replacing their thinking (Henriksson, 2025; Li, 2024; Chen, 2025; Yapar, 2026; Mohammed et al., 2026). In this study, teachers acted as facilitators, allowing children to make decisions while still receiving enough support to remain engaged and persistent.

Fourth, the intervention encouraged reflective strategy adaptation. Children were required to evaluate whether a route worked, revise their choices, and try again. This process is consistent with research on design thinking, computational thinking, robotics, and early problem-solving, which shows that young children can engage in iterative reasoning when tasks are meaningful and appropriately scaffolded (Grönman et al., 2025; Badr et al., 2025; Zviel-Girshin, 2025; Torres-Peña et al., 2025). Therefore, the SLR evidence strengthens the interpretation that the observed improvement was not incidental, but was supported by identifiable cognitive and pedagogical mechanisms. The integration of quantitative findings and SLR evidence demonstrates that exploratory maze-based learning supports problem-solving development through a dynamic combination of movement, spatial reasoning, executive function, trial-and-error, and guided facilitation. This confirms that problem-solving in early childhood develops most effectively when children are given opportunities to explore, make decisions, experience manageable failure, and reflect on their strategies within a supportive learning environment.

CONCLUSIONS

This study demonstrates that exploratory maze-based learning significantly enhances young children's problem-solving abilities by fostering active engagement, strategic thinking, and adaptive decision-making. The quantitative findings reveal a clear improvement in children's independence, as reflected in the increased number of children able to solve problems autonomously and the reduction in those requiring assistance or experiencing difficulties. These improvements are not only evident in overall performance but also across key dimensions of problem-solving, including understanding the problem, planning strategies, executing solutions, and evaluating outcomes. The integration of quantitative results with systematic literature review (SLR) findings provides a comprehensive explanation of the underlying mechanisms driving these improvements. Specifically, exploratory maze-based activities activate executive function processes, such as working memory, cognitive flexibility, and inhibitory control, while also engaging children in embodied learning and spatial reasoning. Furthermore, the role of guided facilitation enables children to gradually transition from supported to independent problem-solving. Overall, this study advances the field by offering an evidence-informed, mechanism-based understanding of how exploratory, movement-based learning environments can effectively support cognitive development in early childhood education

LIMITATION & FURTHER RESEARCH

Despite its contributions, this study has several limitations that should be considered. First, the use of a pre-experimental one-group pretest–posttest design limits the ability to establish causal relationships, as the absence of a control group makes it difficult to fully attribute improvements solely to the intervention. Second, the study was conducted within a single early childhood education setting with a relatively small sample size, which may limit the generalizability of the findings to broader contexts. Third, the measurement of problem-solving abilities relied on observational data, which, although developmentally appropriate, may be subject to observer bias.

Future research is recommended to employ more rigorous experimental designs, such as randomized controlled trials, to strengthen causal inference. Expanding the study across multiple institutions and diverse socio-cultural contexts would also enhance external validity. In addition, future studies could integrate longitudinal approaches to examine the sustainability of problem-solving development over time. Further exploration is also needed to investigate how different types of exploratory activities, including digital, hybrid, or nature-based maze environments, may differentially influence executive function and problem-solving processes. Finally, incorporating advanced analytical approaches, such as structural equation modeling or mixed-methods integration techniques, may provide deeper insights into the relationships between cognitive mechanisms and learning outcomes.

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