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LEARNING CONDITIONS SUPPORTING THE DEVELOPMENT OF CHILDREN'S LOGICAL OPERATIONAL ABILITIES

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Abstrak
Kemampuan operasi logis merupakan fondasi penting bagi perkembangan kognitif anak dan berperan dalam prestasi anak di sekolah. Meskipun pembelajaran berbasis permainan telah banyak diterapkan untuk mengembangkan kemampuan tersebut, penelitian terdahulu lebih banyak berfokus pada efektivitas permainan dibandingkan kondisi pembelajaran yang mendukung keberhasilannya. Penelitian ini bertujuan mengidentifikasi kondisi pembelajaran yang mendukung perkembangan kemampuan operasi logis anak dalam pembelajaran berbasis permainan. Penelitian menggunakan pendekatan kualitatif eksploratif dengan melibatkan tiga taman kanak-kanak dan tiga sekolah dasar di Tiongkok. Data dikumpulkan melalui observasi kelas, wawancara semi terstruktur, studi kasus, dan analisis dokumen, kemudian dianalisis menggunakan thematic analysis. Hasil penelitian mengidentifikasi empat kondisi pembelajaran utama yang mendukung perkembangan kemampuan operasi logis anak, yaitu desain permainan yang sesuai dengan karakteristik perkembangan kognitif anak, bimbingan guru yang adaptif melalui scaffolding, lingkungan belajar yang mendukung proses eksplorasi dan interaksi, serta partisipasi aktif anak selama pembelajaran. Penelitian ini memberikan kontribusi pembelajaran berbasis permainan yang menempatkan kondisi pembelajaran sebagai komponen utama dalam merancang pengalaman belajar yang bermakna dan mendukung perkembangan kemampuan operasi logis anak.

Kata Kunci: Kondisi Pembelajaran; Kemampuan Operasi Logis; Pembelajaran Berbasis Permainan

Abstract
Logical operational skills are a crucial foundation for children's cognitive development and play a role in their academic achievement. Although game-based learning has been widely applied to develop these skills, previous research has focused more on the effectiveness of the games themselves rather than on the learning conditions that support their success. This study aims to identify the learning conditions that support the development of children's logical operational skills in game-based learning. The study employed an exploratory qualitative approach involving three kindergartens and three elementary schools in China. Data were collected through classroom observations, semi-structured interviews, case studies, and document analysis, and were subsequently analyzed using thematic analysis. The results identified four key learning conditions that support the development of children's logical operational skills: game design that aligns with children's cognitive developmental characteristics; adaptive teacher guidance through scaffolding; a learning environment that supports exploration and interaction; and children's active participation during learning. This study contributes to the field of game-based learning by positioning learning conditions as a key component in designing meaningful learning experiences that support the development of children's logical operational skills.

Keywords*: Learning Conditions; Logical Reasoning Skills; Game-Based Learning*

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INTRODUCTION

Logical operation ability is one of the fundamental foundations of children's cognitive development, as it provides the basis for systematic thinking, reasoning, problem-solving, and decision-making across various learning situations. This ability enables children to develop skills in classification, sequencing, comparison, recognition of cause-and-effect relationships, and drawing conclusions based on information obtained from their surrounding environment. Logical operation ability remains important and is widely applied even when individuals reach adulthood (Debrenti & Bordás, 2023). In the context of 21st-century education, logical operation ability contributes not only to children's success in learning mathematics and science but also serves as a prerequisite for the development of critical thinking, computational thinking, and problem-solving skills, which are increasingly required in various life and learning contexts. Research has shown that logical reasoning skills developed from an early age are positively correlated with learning achievement and support the understanding of increasingly complex logical concepts (Larkin et al., 2023). Similarly, the implementation of technology-based robotic games has been reported to facilitate the development of children's logical operation abilities, systematic thinking, and computational thinking, although guidance is still required throughout the learning process (Critten et al., 2022). Therefore, developing logical operation abilities from an early age is an important educational goal for preparing children to face increasingly complex learning demands while building the higher-order thinking skills required in the future.

Although logical operation ability is an important foundation for children's cognitive development, various empirical findings indicate that mastery of these abilities remains a challenge in different countries. In China, a survey conducted by the Chinese Academy of Educational Sciences in 2024 involving 18,000 children aged 5–9 years across 22 provinces showed that only 39.2% of children aged 5–6 years had mastered basic conservation skills, while more than half of the children continued to experience difficulties in classification, causal reasoning, and logical deduction. A report by the Ministry of Education of China in 2023 also indicated that only 45.7% of children aged 5–9 years had met the criteria for logical thinking ability. Similar conditions have also been observed internationally. The 2023 PISA for Early Childhood Extension Study and the 2022 UNESCO report indicated that a substantial proportion of elementary school-aged children still experience difficulties with causal reasoning and basic logical operations, which subsequently affect their learning of mathematics and science at higher educational levels. This phenomenon is not limited to early childhood but also persists at higher levels of education. Research in Indonesia has shown that students continue to experience difficulties in applying logical operations across various mathematical contexts and more complex problem-solving situations, even when they have already understood basic logical concepts (Kodirun et al., 2025). Similar findings were reported by another study, which showed that weaknesses in logical reasoning remain one of the main causes of university students' errors when solving mathematical analysis problems (Isnani et al., 2020). These findings indicate that developing logical operation abilities from an early age remains an educational challenge that requires learning strategies capable of facilitating children's cognitive development more effectively.

As a learner-centered instructional approach, game-based learning is considered to have considerable potential for supporting the development of children's logical operation abilities through active, contextual, and meaningful learning experiences. Systematically designed play activities enable children to explore problems, develop solution strategies, identify cause-and-effect relationships, and construct knowledge through direct interaction with the learning environment. Various studies have shown that game-based learning not only increases learning engagement and motivation but also provides immersive learning experiences that can improve learning outcomes

and support the development of learners' cognitive abilities (Xu et al., 2023). In the context of thinking development, game environments can also facilitate the development of computational thinking through systematic problem-solving activities, allowing children's performance during gameplay to reflect the development of their reasoning abilities and thinking strategies (Liu, 2024). These findings are consistent with other research demonstrating that game-based learning can effectively improve children's logical thinking skills through activities involving observation, exploration, experimentation, and analysis (Nur Fadilah et al., 2025). The findings of Liang and Sitthiworachart (2023) further support this perspective by demonstrating that game-based learning can improve students' motivation, engagement, and understanding of mathematical concepts (Liang & Sitthiworachart, 2023). Therefore, game-based learning is increasingly regarded as a promising approach for facilitating the development of children's logical operation abilities from an early age.

Although various studies have demonstrated that game-based learning has positive effects on children's cognitive development, motivation, and learning engagement, its implementation has produced diverse findings across different learning contexts. Recent meta-analyses indicate that game-based learning has moderate to high effects on various aspects of child development; however, further research is needed to clarify the factors that influence successful implementation (Alotaibi, 2024). On the other hand, most previous studies have focused on developing game-based media, measuring the effectiveness of games on learning outcomes, or evaluating specific cognitive aspects such as creativity, problem-solving, and logical thinking abilities (Weng, 2022). Although several studies have begun to highlight the importance of teacher scaffolding and teacher–child interaction during game-based learning, research examining how various learning conditions, including activity design, teacher roles, learning interactions, and children's engagement, interact with one another to support the development of logical operation abilities remains relatively limited (Sun et al., 2023). These findings are further supported by a systematic review indicating that most game-based learning research remains oriented toward technologsssy and learning outcomes, while studies examining the implementation conditions that support the success of game-based learning have received comparatively limited attention (Guan et al., 2024). Therefore, research is needed not only to evaluate the effectiveness of game-based learning but also to identify the learning conditions that support the development of children's logical operation abilities during game-based learning processes.

Based on this research gap, this study aims to identify the learning conditions that support the development of children's logical operation abilities in game-based learning. This study comprehensively examines various learning conditions, including game design, teacher roles, learning environment support, and children's interactions during gameplay, to understand how each aspect contributes to the development of logical operation abilities. By integrating perspectives from early childhood education, cognitive psychology, and game-based learning, this study is expected to broaden the understanding of learning conditions that support the development of children's logical operation abilities and provide a conceptual foundation for designing more effective game-based learning environments.

METHOD

This study employed an exploratory qualitative approach to gain an in-depth understanding of the learning conditions that support the development of children's logical operation skills in game-based learning. The study was conducted in four stages: preparation, data collection, data analysis, and the preparation of the report, conclusions, and recommendations. The preparation stage included a literature review, instrument development, determination of the research site and participants, and a preliminary study conducted in four schools to refine the research instruments. Data collection was

carried out over a period of four months through classroom observations and case studies. Observations were conducted in 20 classes, comprising 10 kindergartens and 10 elementary schools, with three observations conducted in each class, resulting in 60 observation records focusing on game design, teacher guidance, learning interactions, and children's performance. The case study involved 12 children purposively selected from three public kindergartens and three public elementary schools in a city in China based on variations in their logical operation skills. To obtain more comprehensive data, classroom teachers and parents were also interviewed as supporting sources of information. The primary instrument in this study was the researcher, who was directly involved in the processes of observation, interviewing, and data interpretation. To support consistency in data collection, this study employed the Classroom Observation Scale for Game Teaching of Children's Logical Operation Skills, which was developed based on a literature review and refined through a preliminary study. The blueprint of the observation instrument is presented in detail in Table 1. Each observation indicator was accompanied by a four-level assessment rubric to assist observers in conducting consistent observations throughout the data collection process. In addition, the study employed semi-structured interview guidelines to explore the experiences, perceptions, and views of children, teachers, and parents regarding the learning conditions that support the development of children's logical operation skills in game-based learning.

Table 1. Observation and Interview Instrument Grid

Dimension	Description	Number of Item
Game design	Alignment of game design with the goals of developing logical operational abilities	5
Teacher guidance	Strategies and quality of teacher guidance during learning	5
Instructional interaction	Learning environment that includes teacher-child and peer-to-peer interactions during learning	4
Child performance	Children's participation and logical operational abilities during learning	4

Before being used in the main study, all instruments underwent a validation process conducted by three education experts and two experienced teachers, followed by a preliminary study to evaluate the clarity of the indicators, the feasibility of the observation procedures, and the appropriateness of the interview guidelines. The results indicated that the instruments demonstrated good content validity (CVI = 0.91), high internal reliability (Cronbach's $\alpha = 0.889$), and adequate inter-rater reliability (ICC = 0.862), indicating that they were suitable for use in the main study. Data analysis was conducted using thematic analysis as proposed by Braun and Clarke to identify themes that explain the learning conditions supporting the development of children's logical operation skills. All data obtained were transcribed, organized, and compiled into an integrated database to facilitate the analysis process (Braun & Clarke, 2022). Subsequently, the data were analyzed through initial coding, grouping related codes into themes, and reviewing the themes until representative themes reflecting the overall dataset were established. The final interpretation was conducted by comparing multiple data sources, thereby producing a comprehensive understanding of the learning conditions that support the development of children's logical operation skills.

RESULT

This study adopted a purely qualitative research paradigm, as revised within the thesis framework, incorporating semi-structured interviews, participatory and non-participatory classroom observations, case tracking, and document analysis to collect empirical data. Formal data collection was conducted from March to June 2025 in three senior public kindergartens and three public elementary schools serving Grades 1–2 in a medium-sized city in eastern China. A total of 60 valid classroom observation records, 63 valid interview transcripts (12 children, 12 classroom teachers, and 39 parents), 12 complete child case portfolios, and 117 valid teaching documents (game lesson

plans, teaching reflection records, and children's game outcomes) were included in the final thematic analysis. All qualitative data were transcribed, coded, and verified through researcher triangulation and expert auditing, with a coding consistency rate of 0.87, thereby meeting the standards of rigor for high-quality qualitative educational research (Braun & Clarke, 2022).

The overall coding results indicated that game design conditions received the lowest score among the four dimensions, making them the primary limiting factor in the development of logical operation skills. First, the relevance of game content was inadequate. Only 28.3% of the observed game activities established a clear single logical skills training objective; most integrated entertainment games randomly combined classification, sequencing, and causal reasoning tasks, making them inconsistent with the progressive cognitive development of children aged 5–9 years. For senior kindergarten children aged 5–6 years, most games placed excessive emphasis on practical operations while neglecting conservation thinking training. For lower-grade elementary school children aged 7–9 years, game designs insufficiently incorporated two-step deductive tasks and reversible thinking, which were inconsistent with the cognitive characteristics of the concrete operational stage.

Second, the adaptation of game difficulty was relatively homogeneous. A total of 71.7% of teachers implemented uniform difficulty designs in mixed-ability classes without providing differentiated difficulty levels based on children's working memory and executive function abilities. Interview data from nine frontline teachers indicated that most teachers designed games according to the average ability level of the class, thereby providing insufficient low-threshold participation tasks for children with weak inhibitory control and insufficient extended challenging tasks for children with strong logical foundations.

Third, the practical relevance of game activities remained limited. Most collective game activities prioritized classroom participation and atmosphere, while repeated practice of specific skills occurred fewer than twice per game session. Consequently, these activities were insufficient to establish robust experiences in logical operations.

The teacher guidance dimension demonstrated clear polarization in guidance behaviors. Qualitative data indicated that senior teachers with more than five years of experience in early childhood and elementary education demonstrated better guidance performance, whereas novice teachers exhibited notable weaknesses in instructional guidance. In terms of guidance timing, 45% of novice teachers intervened prematurely when children encountered logical reasoning difficulties, directly replacing the children's independent thinking processes. Meanwhile, 32% of teachers intervened too late, resulting in negative frustration among children and their withdrawal from logical exploration activities.

Regarding guidance methods and feedback effectiveness, closed-ended questions and demonstrative instruction accounted for 69% of all guidance behaviors, whereas open-ended heuristic questions and perspective-shifting guidance were rarely employed. Combined with the analysis of executive function theory, the findings indicated that most teachers were unable to design targeted guidance to help children suppress irrelevant perceptual interference during games or guide them in flexibly updating classification criteria. In addition, 61.5% of teacher feedback consisted of evaluative praise such as “very good,” which lacked targeted connection-based feedback linking game behaviors to logical concepts, thereby hindering children's internalization of logical operation rules. In terms of professional cognitive knowledge, only 27.8% of the interviewed teachers systematically understood the developmental characteristics of children's executive functions and logical operation skills.

Environmental support included the classroom instructional-material environment and the home–school cooperation environment, with a notable imbalance between in-school and out-of-school support. Regarding the classroom instructional-material environment, most kindergartens and elementary schools were equipped with basic sorting blocks and reasoning card materials. However, the arrangement of instructional materials was relatively fixed and could not be adapted to the increasing difficulty levels of games. Functional play areas focusing on causal reasoning and reversible thinking also remained insufficiently developed within the school environment.

Regarding the home–school interaction environment, this study identified a serious mismatch between family-based logical game practices and game-based instruction at school. Statistical data from the parent questionnaire showed that only 20.5% of parents accompanied their children in engaging in specific logical games more than three times per week. Most parents regarded after-school games merely as recreational activities and lacked awareness of the importance of developing children's conservation abilities and deductive reasoning through everyday play. Meanwhile, monthly home–school communication specifically focusing on children's logical development accounted for less than 18% of the total communication content, resulting in fragmented educational effects between the family and school environments.

Children's interactive participation constitutes a primary means of internalizing logical operations and can be divided into peer cooperative interaction and autonomous game interaction. Observation data showed that single-player competitive games accounted for 57% of daily playtime, whereas cooperative reasoning games were conducted less frequently. During peer interaction, children with higher levels of logical ability tended to dominate game decision-making and classification judgments, while children with lower levels of logical ability passively followed group rules and therefore had fewer opportunities to express their own reasoning. From the perspective of age-related differences, kindergarten children aged 5–6 years were more willing to engage in verbal logical communication during peer interactions; however, their limited working memory constrained their ability to engage in multi-perspective reasoning. Elementary school children aged 7–9 years demonstrated basic peer discussion abilities but lacked teacher-mediated interaction rules to guide effective logical dialogue. In addition, children from rural migrant families demonstrated lower levels of active interactive engagement in logical games, with their interactive participation rate being 12 percentage points lower than that of children from urban local families.

DISCUSSION

The findings of this study indicate that the development of children's logical operation skills in game-based learning is not determined by the presence of games themselves, but rather by the quality of the learning conditions that shape children's learning experiences during gameplay. The results demonstrate that the success of game-based learning depends on how play activities are designed, facilitated by teachers, supported by the learning environment, and structured to encourage children’s active involvement in constructing their own knowledge. These findings are consistent with the perspective of constructivist learning theory, which positions game-based learning as a pedagogical approach whose effectiveness is determined by the process of knowledge construction through meaningfully designed learning experiences, rather than by the use of games alone (Pill et al., 2023). These findings also reinforce the results of a systematic review indicating that the effectiveness of digital game-based learning depends on the integration of game design, pedagogical strategies, and the teacher’s role (Tay et al., 2022), and are consistent with various studies emphasizing that the quality of learning cannot be established through a single component in isolation, but requires the integration of teacher competence, student-centred pedagogical approaches, and adequate learning environment and infrastructure support (Chrishanty et al., 2025;

Hilhamsyah et al., 2024; Sabariah et al., 2025). Thus, game-based learning should be viewed as a learning system that integrates various complementary pedagogical conditions to support the development of children's logical operation skills.

Games designed according to children's cognitive developmental characteristics and learning objectives provide opportunities for children to explore, test various problem-solving strategies, and gradually develop logical reasoning. However, this potential can only be optimally realized when supported by teacher guidance through appropriate directions, prompting questions, feedback, and scaffolding tailored to children's learning needs. These findings are consistent with Piaget's perspective, which positions play as a primary medium through which children construct knowledge through direct experience, while also reinforcing Vygotsky's perspective, which emphasizes the importance of adults in facilitating learning through interaction and guidance during play (Mauluddia & Solehuddin, 2023; Veraksa et al., 2022). Previous studies have also shown that the effectiveness of game-based learning is determined not only by the quality of game design, but also by the appropriate implementation of scaffolding and the alignment among game design, learning theory, and learning objectives (Hou et al., 2023; Ramli et al., 2022). Therefore, the findings of this study reinforce the view that the development of children's logical operation skills is determined more strongly by the integration of meaningful game design and adaptive pedagogical strategies employed by teachers than by the characteristics of the games themselves. Accordingly, learning quality should be understood as the result of interactions among various complementary pedagogical components (Yu et al., 2024).

A supportive learning environment and active child participation constitute learning conditions that strengthen the process of knowledge construction during game-based learning. The findings demonstrate that the learning environment should not be understood merely as the physical space in which learning takes place, but also as encompassing psychological, social, cultural, and pedagogical dimensions that collectively shape children's learning experiences and enhance their motivation, engagement, and learning outcomes (Rusticus et al., 2023). In the context of game-based learning, a learning environment designed to encourage exploration, collaboration, dialogue, and reflection provides children with opportunities to develop logical understanding through active and meaningful learning experiences, consistent with the characteristics of game-based learning, which utilizes games as a means of creating interactive learning environments (Cabrera-Solano, 2022). Furthermore, active engagement in interactions with teachers and peers provides children with opportunities to test their reasoning, exchange ideas, and construct knowledge collaboratively, which are key characteristics of constructivist learning environments and contribute to the development of higher-order thinking skills (Do et al., 2023). This finding is further supported by research demonstrating that instructional designs that explicitly facilitate thinking and reasoning processes can enhance student engagement while enabling teachers to identify the development of logical thinking skills during learning activities (Peters-Burton et al., 2026). Conversely, providing students with opportunities to exercise control over aspects of their learning process has also been shown to enhance motivation and learning quality, making active child participation an important component in the development of logical operation skills (Hauk & Gröschner, 2022). These findings are also consistent with research emphasizing that an effective learning environment is constructed through the integration of classroom climate, resources, and learning conditions that support student well-being and engagement (Muñoz-Troncoso & Riquelme, 2025), while reinforcing the view that learning outcomes result from a combination of complementary instructional conditions (Dallavis & Berends, 2023). Therefore, the development of children's logical operation skills in game-based learning should be understood as the outcome of active engagement within a learning environment rich in interaction, collaboration, and opportunities for knowledge construction, which ultimately

provides an important foundation for the development of reasoning skills required in 21st-century learning (Bronkhorst et al., 2022).

The findings of this study indicate that the development of children's logical operation skills in game-based learning results from the integration of various complementary learning conditions. These results suggest that the effectiveness of game-based learning is more appropriately understood as the product of the integration of game design, teacher guidance, learning environment support, and active child participation, which collectively shape meaningful learning experiences (Nafratilova & Degeng, 2025). This perspective is consistent with the student-centred experience approach, which positions the quality of learning experiences as the result of the integration of instructional design, educator roles, and learning implementation, while reinforcing the view that learning outcomes are influenced by a combination of instructional conditions rather than by a single learning component in isolation (Coleman & Money, 2024; Dallavis & Berends, 2023). These findings also extend existing research on game-based learning, which has predominantly focused on game effectiveness, by demonstrating that a comprehensive understanding of instructional impacts requires attention to the integration of various learning conditions, allowing games to function as part of a meaningful learning strategy rather than merely as learning media (Arifa et al., 2018; Sumiyati & Surjono, 2026). At the same time, the growing availability of technology supporting the development of game-based learning should be considered, as logical thinking skills have consequently become an increasingly important competency (Laksana, 2024).

This study implies that the design of game-based learning should consider the integration of various learning conditions that shape students' learning experiences. The development of game-based learning should be directed toward designing a learning system that integrates play activity design, teachers' pedagogical strategies, learning environment support, and active student participation as a unified and complementary whole. This perspective provides a conceptual contribution to the development of game-based learning design by positioning learning conditions as a central component determining the quality of learning experiences and the development of children's logical operation skills. Thus, this study extends the understanding of game-based learning beyond an approach that merely utilizes games toward a comprehensive learning system deliberately designed to support children's cognitive development.

CONCLUSION

This study demonstrates that the development of children’s logical operation skills in game-based learning is not determined solely by the use of games as instructional media, but rather by the integration of various learning conditions that shape children’s learning experiences throughout the gaming process. Thematic analysis identified four key learning conditions: game design aligned with children’s cognitive developmental characteristics, adaptive teacher guidance, a supportive learning environment, and children’s active participation in the learning process. These findings extend the perspective on game-based learning by demonstrating that its effectiveness is determined more by the quality of instructional design and pedagogical strategies than by the characteristics of the games themselves. Therefore, this study contributes to the field of Educational Technology by emphasizing that game-based learning should be designed as an integrated system of learning conditions to create meaningful learning experiences and support the development of children’s logical operation skills.

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