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Review

Influencing Factors and Intervention Strategies of Early Mathematical Cognition

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Abstract: Early mathematical cognition constitutes a critical foundation for children's subsequent academic achievement and broader cognitive development. Its growth is shaped by multiple interacting factors, including the family environment, parental beliefs and behaviors, school experiences, and the increasing presence of digital resources in children's daily lives. With the rapid popularization of information technology and the transformation of family education models, clarifying the mechanisms through which these factors operate has important theoretical and practical significance. This review synthesizes major theoretical perspectives on early mathematical cognition, such as number sense, spatial reasoning, and logical thinking, and summarizes empirical findings on how family learning atmosphere, parent–child interaction, and guided use of digital tools support these core abilities. Particular attention is given to the complementary roles of family-based activities and digital learning platforms, which together can enrich children's opportunities for mathematical exploration and practice. The review further discusses intervention strategies at the levels of parents, schools, and communities, including parental education programs, guidance on the selection and use of digital resources, curriculum optimization, and multi-agency collaboration. Current research is limited by a predominance of cross-sectional designs, insufficient longitudinal and causal evidence, and a lack of attention to cultural and socioeconomic diversity. Future studies should adopt diversified, long-term, and cross-cultural approaches to refine evidence-based interventions and promote the sustainable development and wider dissemination of high-quality early mathematics education.

Keywords: early mathematics; cognitive development; family environment; parental behavior; digital resources; educational intervention

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1. Introduction

1.1. Research Background

The early development of mathematical cognition is a crucial aspect of children's cognitive growth and significantly influences future academic performance. Early mathematical skills are closely linked to later achievements in mathematics and serve as an important indicator for performance in subjects such as science and logical thinking. From a cognitive perspective, mathematical learning exhibits a strong positive correlation with executive functions, including working memory, inhibitory control, and cognitive flexibility. Enhancing executive functions improves problem-solving abilities and the application of strategies, while cognitive flexibility facilitates the adaptation of multiple strategies and the resolution of complex problems, directly impacting the formation of children's mathematical concepts. Non-cognitive factors, such as math anxiety, can impede mathematical learning, as high levels of anxiety lead to distraction and inefficient allocation of cognitive resources, thereby affecting performance. In neuroscience, structural and functional abnormalities in the brain, such as underdevelopment of the

parietal cortex, are associated with mathematical learning disabilities. An unstable foundation in early mathematics can trigger long-term negative effects, with insufficient mathematical ability in lower grades strongly correlating with academic difficulties in middle school. Addressing the development of early mathematical cognition and meeting the needs of children's individual growth is essential for fostering scientific literacy at a national level [1].

1.2. Research Purpose

This study aims to systematically organize the key elements influencing the development of children's early mathematical cognition, summarize feasible intervention measures, and design an integrated program encompassing family, school, and policy levels. The specific tasks include analyzing the mechanisms of cognitive variables such as language ability, executive functions, working memory, and number concepts; exploring the role of family language atmosphere, daily mathematical practices, educational resource allocation, and cultural background in shaping number concepts; identifying empirically supported intervention paradigms, such as contextualized arithmetic teaching, interactive explanation and reflective communication, teacher professional development, and home-school cooperation; and proposing implementation suggestions focusing on early intervention, long-term follow-up, and practical interventions [2]. It emphasizes equitable participation of resource-limited groups, aiming to enhance the standard of children's mathematical development and their long-term learning potential.

1.3. Structure of the Paper

This paper is divided into seven chapters, with a well-structured content layout and clear organization. Chapter One serves as the introduction, presenting the research background and objectives, along with an overview of the paper's arrangement. Chapter Two explores the academic foundations of early mathematical cognition, addressing the core elements of cognitive development theories, quantitative standards of key concepts, and evaluation methods, thereby establishing a theoretical basis for subsequent research. Chapter Three identifies the key factors influencing the development of young children's mathematical cognition, including parental rearing styles, family atmosphere, and the accessibility of digital media resources. Chapter Four delves into the mechanisms through which these factors exert their influence. Chapter Five proposes specific intervention measures and implementation strategies, discussed across three dimensions: family environment, campus and community support, and digital platforms. Chapter Six highlights the limitations of the research, such as methodological shortcomings and the absence of long-term follow-up studies, while also suggesting directions for future research. Chapter Seven concludes by summarizing the influencing factors and effective intervention measures, offering guidance for future research and practical applications [3].

2. Theoretical Foundations of Early Mathematical Cognition

2.1. Cognitive Development Theory

The grasp of early mathematical cognition cannot be separated from the core theoretical framework provided by cognitive development theory [4]. Piaget's cognitive stage theory has broad influence. Piaget divides children's cognitive development into four stages, among which the sensorimotor stage (0–2 years) and the preoperational stage (2–7 years) are most closely related to early mathematical cognition. In the sensorimotor stage, children explore the world through sensory experiences and bodily activities, gradually establishing initial cognition of quantity and space, distinguishing differences in object size and quantity. Upon entering the preoperational stage, children begin to think using symbols and imagery, with thinking showing egocentric and irreversible characteristics. Children at this stage, although capable of completing basic classification and ordering tasks in mathematical cognition, find it difficult to grasp the concept of conservation.

This viewpoint holds that the improvement of children's cognitive ability mainly relies on the two processes of assimilation and accommodation. In the early stage of mathematical learning, children integrate new mathematical concepts into existing cognitive frameworks [5]. Once the original cognitive system cannot accommodate new knowledge, they actively adjust and optimize their thinking structure. This theory suggests that when conducting early mathematics education, it is necessary to follow the stage characteristics of children's cognitive development, provide them with appropriate learning resources and activity forms, and effectively promote the growth of their mathematical thinking ability.

2.2. Core Concepts of Mathematical Cognition

Spatial reasoning and logical thinking, together with number sense, jointly constitute the foundational elements of early mathematical cognition. Number sense refers to children's intuitive grasp and understanding of quantity, encompassing awareness of object quantity, size, and order. For example, children can visually distinguish which of two piles of objects is larger [6]. Perceptual ability is a key prerequisite for smooth future mathematical computation learning.

Spatial reasoning concerns children's cognition and processing of objects' positions, orientations, and shapes [7]. Through games such as stacking blocks and assembling puzzles, children gradually understand spatial relations and cultivate spatial imagination. This ability helps children grasp geometric shapes and solve mathematics problems related to space.

Logical thinking occupies a core position in mathematical cognition. During early childhood, children engage in practical activities such as classification and ordering patterns to exercise logical thinking skills. They are guided to classify blocks of different colors or shapes, or to arrange items according to specific patterns. The improvement of logical thinking ability helps children think more systematically about mathematical problems, laying a solid foundation for subsequent mathematical learning. These three core concepts are interrelated and jointly support the development of children's early mathematical cognition [8].

2.3. Measurement Indicators and Assessment Tools for Early Mathematical Cognition

Early mathematical cognition measurement indicators and tools for assessing children's mathematical development play a crucial role in designing individualized educational programs [9]. These indicators typically encompass multiple dimensions, including number concepts, calculation skills, spatial cognition, and logical reasoning. At the number concept level, children's abilities to recognize numbers, count, and compare quantities can be evaluated, while calculation skills focus on assessing their performance in addition and subtraction operations.

Commonly used assessment tools include standardized tests, observation scales, and task analysis. Standardized tests, known for their high reliability and validity, are used to quantitatively evaluate children's mathematical abilities, such as their early mathematical skills. Observation scales document children's mathematical performance in daily activities, such as their use of quantity and spatial relationships during play, to assess their cognitive development in mathematics [4]. Task analysis involves having children complete specific mathematical tasks and analyzing their problem-solving processes and strategies to uncover their thinking patterns and mathematical proficiency. By integrating various measurement indicators and assessment methods, educators and parents can gain a comprehensive understanding of children's early mathematical cognition and provide more targeted support and guidance.

3. Major Factors Affecting Early Mathematical Cognition

3.1. Parental Behavior

3.1.1. Educational Behavior

Parental guidance plays a crucial role in the development of children's early mathematical cognition. Parents organize mathematical games and explain mathematical concepts to children, guiding them to participate in activities such as number sequencing or comparing card values. In a relaxed and pleasant atmosphere, parents help children grasp the order and magnitude of numbers. Through continuous game interactions, children's number sense significantly improves, enabling them to react and make judgments more quickly [10].

When explaining mathematical concepts, vivid and concrete descriptions by parents help children better understand abstract mathematical knowledge. For example, using "You have 3 candies, and mom gives you 2 more [11]. How many candies are there now?" allows children to intuitively grasp the meaning of addition. Additionally, parents can adjust the explanation method and pace according to children's responses during the process, ensuring genuine understanding. Personalized education effectively stimulates children's interest in mathematics, laying a solid foundation for their subsequent mathematical learning.

3.1.2. Family Interaction

In family interactions, parent-child reading and counting activities provide valuable learning opportunities for children's early mathematical cognition. Using math-themed picture books for parent-child reading is an effective approach. During reading, children are introduced to various math-related scenarios and concepts. Content such as the number of animals or shapes in the illustrations allows parents to guide children in observing the pictures and asking related mathematical questions. This process enhances children's observation skills and fosters their ability to apply mathematical knowledge to solve practical problems [12].

Counting activities are common and effective in family interactions. For instance, counting steps while going up and down stairs or having children count items during shopping trips [13]. Through these daily counting activities, children gradually learn number order and quantity correspondence. Such interactions also strengthen parent-child relationships, enabling children to approach mathematics more proactively in a supportive family environment, thereby subtly promoting the development of mathematical cognition.

3.1.3. Parents' Mathematical Beliefs and Attitudes

Parents' beliefs and attitudes toward mathematics significantly influence the development of children's early mathematical cognition. If parents view mathematics as an enjoyable and practical subject and exhibit a positive attitude toward it in daily life, children are likely to be inspired by this positive environment and develop a favorable perception of mathematics. When parents confidently and effectively handle mathematical tasks in everyday situations, such as calculating shopping discounts or managing family finances, children recognize the importance of mathematics in daily life, which fosters their intrinsic motivation to learn the subject [14].

Conversely, if parents harbor fear or negative attitudes toward mathematics, children are likely to absorb these negative emotions and perceive mathematics as a challenging subject. For example, if parents frequently express frustration about the difficulty of mathematics, children may quickly adopt the belief that it is a subject too difficult to master, leading to a lack of enthusiasm for learning [12]. Parents should cultivate a constructive perspective on mathematics and maintain a positive attitude, thereby creating a supportive psychological environment for their children's mathematics education.

3.2. Family Environment

3.2.1. Family Digital Resources

The abundant digital resources in the family environment significantly influence children's early mathematical cognitive development. For instance, building blocks allow children to directly engage with shapes, sizes, and spatial relationships during the construction process. Counting activities help them grasp the concept of quantity. Puzzle-type toys enhance logical reasoning and spatial discrimination abilities. Mathematical-related reading materials, presented through story narration and interactive games, vividly convey mathematical principles, stimulating children's interest in the subject. These materials introduce basic concepts such as numbers and graphics in an enjoyable reading experience. Electronic devices like tablets offer mathematics learning programs that, through interactivity and entertainment, encourage children to actively participate in learning. Features such as animation demonstrations and game-based designs assist in understanding abstract mathematical concepts. Parents should guide children in using these resources scientifically and ensure they do not develop excessive dependence on digital devices.

3.2.2. Family Learning Atmosphere

Creating a positive family learning environment significantly enhances children's early mathematical cognition. When children achieve small breakthroughs in learning mathematics, timely affirmation and encouragement from parents, such as verbal praise or small rewards, can boost their self-efficacy and enthusiasm for learning [9]. When children face challenges, parental emotional support and collaborative exploration of problem-solving methods help them understand that they are not tackling difficulties alone. Guiding children to observe mathematical examples in daily life, such as store price tags or household item counting, and encouraging them to ask questions and attempt solutions independently, is essential for fostering interest in mathematics. A supportive learning atmosphere enables children to view mathematics as an enjoyable exploration rather than a tedious task, motivating them to actively engage in acquiring and understanding mathematical knowledge.

3.2.3. Family Structure and Socioeconomic Background

Children's early mathematical cognition is significantly influenced by family structure and socioeconomic background. In a complete and harmonious family, children benefit from stable emotional support and learning guidance. When both parents actively participate in children's mathematical learning, they provide multidimensional stimulation. Families with stronger socioeconomic conditions can often offer higher-quality math learning opportunities, such as professional tutoring and advanced learning tools. Conversely, families with limited economic resources may encounter challenges in accessing such resources [10]. However, family composition and economic status are not the sole determinants of children's mathematical development. Even in resource-constrained environments, parental involvement, guidance, and the creative use of free resources in daily life—such as exploring natural patterns outdoors for mathematical inspiration—can effectively enhance children's mathematical cognition.

3.3. Digital Resources

3.3.1. Digital Games and Applications

Digital games offer an engaging and effective approach to fostering children's early mathematical understanding. Many digital games encourage active participation through vibrant graphics, appealing characters, and challenging levels. For instance, certain math operation games guide children to assist game characters in completing tasks, thereby practicing addition and subtraction while playing. Shape recognition games enable children to learn the characteristics of various shapes through interactive gameplay. Compared to games, digital applications are often more systematic and specific,

providing personalized learning content tailored to children's age and learning level [15]. However, some digital games and applications may include excessive advertisements or vary in content quality. Parents should carefully evaluate these resources to ensure children access high-quality content that aligns with their educational needs.

3.3.2. Online Learning Platforms

Digital learning platforms offer a modern approach to enhancing children's early mathematical cognition. These platforms typically provide extensive teaching materials that span from basic number comprehension to advanced mathematical concepts. The teaching activities available are varied, including video tutorials, interactive exercises, and online quizzes, catering to the personalized learning needs of diverse students. Digital tools are not limited by time or location, enabling students to study at their convenience. Additionally, some platforms feature learning tracking and assessment systems, allowing parents and students to monitor progress and outcomes effectively. However, online learning does have limitations, such as dependence on stable network conditions and the absence of face-to-face interaction [16]. Parents should guide students in using these tools responsibly, fostering good study habits and self-management skills.

3.4. Advantages and Challenges of Digital Family Education

Digital family education demonstrates significant positive effects on children's early mathematical cognition. This approach provides diverse learning materials, overcoming the time and space constraints of traditional education and enabling children to learn at their own pace. The engaging and interactive nature of digital resources effectively captures children's attention and boosts their enthusiasm for learning [13]. Through virtual reality technology, children can experience immersive applications of mathematics in real-life scenarios. However, digital family education also presents several challenges. Extended exposure to electronic devices may adversely impact children's vision and physical health. Some parents lack adequate guidance in selecting digital education resources, which can lead to children encountering inappropriate content. Excessive reliance on digital education may reduce children's interaction with the physical world, potentially hindering the development of practical skills and social abilities.

4. Mechanisms of Influencing Factors

4.1. The Path of Family Interaction Affecting Cognitive Development

In the process of children's mathematical cognitive development, family interaction plays an indispensable role. Parents and children, through daily conversations, games, and learning activities, establish a relationship of mutual support and encouragement, providing children with sufficient cognitive inspiration. During these interactions, parents' language guidance helps children grasp abstract mathematical concepts, counting, comparison, classification, and other basic skills. Positive responses and affirmations from parents effectively enhance children's enthusiasm for learning and self-belief, stimulating deeper cognitive exploration. Family interaction, relying on emotional bonds, creates a safe atmosphere that allows children to maintain patience and perseverance when facing mathematical problems, successfully overcoming challenges. The higher the quality of family interaction, the more children's mathematical performance and cognitive ability are supported. Good family interaction aids in mastering mathematical skills, strengthens children's problem-solving ability, and enhances logical thinking. Parents' attitudes of patient listening, asking questions, and collaborative problem-solving during the learning process are important driving factors for children's cognitive development. The educational atmosphere within the family, the interaction patterns, and the cognitive behaviors of members all have profound impacts on children's attitudes and abilities in mathematical learning. To improve children's mathematical cognitive level, it is necessary to focus on cultivating high-quality family interaction habits, creating a positive and supportive family learning environment, and

laying a solid foundation for the development of children's mathematical cognitive abilities.

4.2. Ways Digital Resources Promote Cognitive Skills

With the rapid development of information technology, digital resources have become essential tools for enhancing children's mathematical cognitive abilities. Online education platforms, interactive games, multimedia teaching software, and learning apps provide engaging and concrete mathematical learning materials, effectively stimulating children's enthusiasm for learning. Animation demonstrations transform abstract mathematical concepts into tangible forms, aiding children in constructing intuitive cognitive models. Interactive software offers instant feedback through practice, exploration, and trial and error, reinforcing understanding and memory. Digital resources enable personalized learning paths by tailoring content to individual cognitive levels and interests, supporting differentiated teaching approaches. The accessibility and variety of digital resources lower barriers to learning, allowing more children to access high-quality mathematical education materials in both family and school environments. Digital platforms, such as virtual experiments and online competitions, create opportunities for collaboration and competition, fostering problem-solving skills and teamwork. Parents and teachers can utilize digital resources to monitor and guide children's learning processes, gaining timely insights into their progress. When used effectively, digital resources can address the limitations of traditional teaching methods, enhance children's mathematical cognitive abilities, nurture autonomous learning skills, and establish a strong foundation for future mathematical learning in the digital era.

4.3. The Model of Parents' Behaviors Regulating the Family Environment and Influencing Children's Mathematical Cognition

In constructing the family learning atmosphere, the role of parents is crucial. Their behaviors, whether direct or indirect, have profound impacts on children's mathematical cognitive development. The family learning environment theory highlights that the overall family atmosphere, parents' educational methods, expectations for cognitive abilities, and the degree of emphasis on mathematical learning are all key elements in shaping children's mathematical cognition. When parents actively engage, provide systematic guidance, and adopt appropriate motivational methods, they create a learning platform for their children that is both supportive and challenging. In daily life, parents can foster children's mathematical thinking abilities through digital games or by solving practical problems using mathematical knowledge. Parents' level of expectation directly influences children's learning enthusiasm, with higher expectations often encouraging children to study mathematics more diligently. Educational methods such as patient listening, providing positive feedback, and encouraging children to embrace mistakes can enhance their confidence and reduce their fear of challenges. The richness of resources in the family environment and the diversity of learning materials significantly contribute to the improvement of cognitive abilities. The cultural atmosphere of the family and its emphasis on mathematical learning also shape children's learning attitudes and influence their long-term development. This theory underscores that parents are not only transmitters of knowledge but also regulators of the learning environment. Their behavioral modeling and environmental creation help children steadily improve their mathematical cognitive abilities [12]. An effective family environment regulation provides children with a stable and stimulating learning space, laying a solid foundation for mathematical learning at an early stage.

5. Intervention Strategies and Practices

5.1. Family Intervention

5.1.1. Parent Education and Training

Parents play a crucial role as children's first mentors, and their mathematical literacy and teaching skills significantly influence the development of children's early mathematical cognition. Special training programs are recommended, where professionals in education can teach parents fundamental mathematical knowledge, including numerical operations, shape recognition, and other related topics, to enhance their mathematical abilities [9]. Scientific teaching strategies should be introduced, such as guiding children to learn calculation methods through practical scenarios like shopping. During the training process, emphasis should be placed on cultivating parents' patience and fostering a positive and encouraging educational attitude, enabling children to engage with mathematics in a relaxed and enjoyable environment. Regular experience-sharing sessions can be organized to encourage parents to exchange educational insights, inspire one another, and collectively improve teaching effectiveness. This approach aims to create a high-quality family environment conducive to children's mathematics learning.

5.1.2. Guided Use of Family Digital Resources

With the continuous progress of technology, digital resources within families are becoming increasingly abundant. When children's use of these resources is effectively guided, their mathematical cognitive abilities can be significantly enhanced. Parents should carefully select mathematics learning software and online courses that are appropriate for their children's age group. Applications that incorporate engaging animations and interactive games can effectively stimulate children's enthusiasm for learning. When children access digital resources, parents should accompany them and provide necessary guidance, helping them master mathematical concepts presented in the software. It is important for parents to reasonably control the time children spend using digital devices to prevent over-reliance. Parents and children can explore mathematical problems in digital resources together, thereby deepening the children's understanding. Additionally, guiding children to apply the knowledge gained from digital resources to daily life is equally important [17]. For instance, after learning about shapes through software, children can be encouraged to identify corresponding shapes in their surrounding environment.

5.1.3. Family Games and Activity Design

Family games and interactions are effective methods for children's early mathematical development. Parents can organize mathematical treasure-hunt activities by preparing cards with numbers or mathematical problems and hiding them in various locations at home. This encourages children to find the cards and solve the problems, fostering their understanding of numbers. Hosting family math competitions and mental arithmetic challenges can inspire children's competitive spirit and enhance their computational abilities. Simulated shopping experiences, where children take on roles such as cashier and customer, provide opportunities to practice currency conversion. Additionally, using building blocks to create various shapes helps children grasp geometric figures and spatial structures. Game-based learning allows children to acquire mathematical knowledge in a relaxed environment, promoting the development of their mathematical thinking skills.

5.2. School and Community Intervention

5.2.1. Mathematical Guidance in Early Childhood Education Courses

Early mathematics enlightenment education is a crucial aspect of children's cognitive development. In teaching planning, mathematical concepts should be introduced progressively, aligning with the cognitive characteristics of young children. For junior

classes, activities such as singing number rhymes and playing number matching games can help children establish foundational number concepts. In middle classes, shape puzzles and object classification activities can be organized to develop shape recognition and logical reasoning skills. Senior classes are suitable for introducing basic addition and subtraction, using object demonstrations to help children understand operational principles. Throughout the teaching process, it is important to emphasize engaging and interactive methods. Story-based teaching can be employed, integrating mathematical knowledge into vivid storylines, allowing children to naturally acquire mathematical concepts while enjoying the narratives [5]. Encouraging active participation in classroom discussions and hands-on activities can further enhance learning outcomes.

5.2.2. Parent-Participated Mathematical Activities

When home-school cooperation is strengthened, children's mathematical cognitive development is also enhanced. Parents' participation in school mathematics activities has a direct impact [18]. Schools can organize parent-child mathematics activity days and design engaging activities such as solving math puzzles together and relay-style calculations. Through interaction and collaboration among family members, children naturally acquire mathematical knowledge during participation. Schools can also offer mathematics workshops for parents, where teachers share strategies to support children's learning of mathematics in the home environment, thereby improving parents' educational approaches and guidance skills. Additionally, activities that invite parents into classrooms can be arranged, allowing them to demonstrate how they apply mathematical knowledge in daily life, thereby broadening children's perspectives. By incorporating diverse activities, parents become more deeply involved in their children's mathematical learning process, fostering a collaborative educational environment.

5.2.3. Community Resource Support

Communities can provide abundant resource support for children's early mathematical cognitive development. Community libraries acquire a wide range of mathematics picture books and popular science readings suitable for children and regularly organize mathematics-themed reading activities, such as story-sharing sessions, allowing children to experience the enjoyment of mathematics through reading. Community activity centers offer mathematics interest classes, inviting professional teachers to provide systematic opportunities for mathematics learning. Community mathematics competitions can be organized to encourage children to actively participate, fostering their sense of competition and teamwork. Additionally, communities can utilize nearby malls, supermarkets, and other locations to conduct on-site teaching activities, enabling children to apply mathematical knowledge in real-life scenarios and enhance their mathematical application abilities.

5.3. Digital Intervention

5.3.1. Design Principles of Digital Learning Platforms

When designing digital learning platforms, it is essential to consider children's characteristics and needs. The platform interface should emphasize simplicity, clarity, and engagement, incorporating colorful and appealing icons and animation elements to effectively capture children's attention. The content organization must demonstrate systematic structure and hierarchy, scientifically planning the progression of mathematical knowledge according to children's developmental stages and cognitive abilities. This ensures a gradual transition from basic number recognition to more complex mathematical operations, maintaining a logical learning process [19]. Interactive features should be enhanced by including diverse sections such as Q&A and games, which can stimulate children's enthusiasm for active learning. Customized learning plans should be offered, intelligently adapting to children's learning feedback to address the needs of

individual learners. Additionally, the platform's safety must be prioritized, with strict measures in place to prevent children from encountering any harmful information.

5.3.2. Effectiveness of Digital Games

Digital games play a crucial role in the early mathematical cognitive development of children. Effective digital games should establish clear educational objectives, using engaging activities to help children master skills such as addition, subtraction, and recognizing geometric shapes [19]. These games should balance entertainment with challenge, incorporating appropriate difficulty gradients to spark children's enthusiasm and encourage them to enhance their mathematical abilities while overcoming obstacles. Breakthrough-style games can be designed with progressively advancing levels and increasing difficulty. Additionally, games should include feedback systems that provide immediate guidance on correctness or errors, enabling children to correct mistakes promptly. Interaction with other participants, such as through competitive games, should also be encouraged to foster a sense of competition and develop social skills. By leveraging well-designed digital games, children's mathematical learning outcomes can be significantly improved.

5.3.3. Strategies for Parent-Guided Use of Digital Resources

Parents play an essential role in guiding children's use of digital resources, helping them select appropriate learning software and games. It is important for parents to familiarize themselves with the content and features of various digital tools. When children engage with these resources, parents should accompany them, collaboratively exploring the mathematical concepts embedded within and assisting in resolving any challenges encountered. Establishing reasonable usage plans is crucial, as parents must strictly regulate screen time to prevent excessive use. Encouraging children to apply acquired knowledge to real-life situations is equally important; for instance, after learning measurement techniques through a mobile application, children can practice by measuring household furniture. Regular communication between parents and children about their experiences and outcomes with digital resources allows for timely adjustments to usage strategies, ensuring optimal effectiveness in applying these tools.

6. Limitations of Existing Research and Future Prospects

6.1. Methodological Limitations

Most studies utilize cross-sectional designs and correlational analyses, which limit the ability to uncover causal relationships and dynamic developmental trajectories. Self-reports and questionnaires are prone to social desirability effects, resulting in potential data bias. Observational methods, while capable of capturing behaviors in natural settings, often lack standardization, reducing generalizability. Experimental studies frequently involve small sample sizes and highly controlled environments, which restrict external validity. Future research should prioritize methodological innovation by combining longitudinal tracking with experimental designs, employing advanced statistical techniques such as multilevel linear modeling, and integrating multi-source data to enhance scientific rigor and reliability.

6.2. Lack of Longitudinal Research and Causal Inference

Current academic discussions often emphasize short-term observational surveys, overlooking the importance of long-term monitoring in early mathematical cognitive development. Consequently, establishing clear causal relationships between influencing factors and mathematical skills remains challenging. For instance, it is uncertain whether family background nurtures mathematical potential or whether children with high potential encourage families to allocate more resources. Future research should prioritize large-scale, multi-wave longitudinal tracking, utilizing cross-lagged panel analysis and structural equation modeling while accounting for confounding variables. Additionally,

techniques such as propensity score matching should be applied to strengthen evidence for causal inference.

6.3. Insufficient Consideration of Cultural and Individual Differences

In research design and implementation, the influence of diverse cultural contexts and individual characteristics has not been adequately addressed, limiting the universality of findings across varied social settings. Overlooking cross-cultural differences can result in interpretive bias and methodological limitations. Many studies are conducted within Western cultural contexts, raising questions about their applicability in other cultural environments. Variations in family values, educational philosophies, and mathematics teaching methods across cultures may significantly shape developmental pathways [12]. Similarly, individual-level differences, such as gender, personality traits, and learning styles, remain underexplored. Future research should prioritize cross-cultural comparative studies, develop localized assessment tools, and apply personalized analytic strategies to better understand developmental trajectories and intervention needs across diverse groups.

6.4. Future Research Directions

Future research could focus on developing multi-dimensional, collaborative intervention programs that integrate family, school, community, and digital resources to build comprehensive support networks. Efforts should also be directed toward establishing long-term tracking systems to examine the sustainability and transferability of intervention effects. Cross-cultural comparative studies could be deepened to explore both universal patterns and regional differences. Furthermore, leveraging big data and artificial intelligence may enable precise assessments and customized interventions [11, 16]. Special attention should be given to marginalized groups to promote educational equity and ensure that every child has access to high-quality early mathematics education.

7. Conclusion

7.1. Summary of Influencing Factors

This study systematically reviewed the core factors influencing early mathematical cognition across three dimensions: parental behavior, family environment, and digital resources. Parental educational practices, the quality of family interactions, and positive mathematical attitudes directly impact children's cognitive development. Family environment factors, such as the richness of digital resources, learning atmosphere, family structure, and socioeconomic background, significantly shape children's mathematical learning experiences. Digital resources, as an emerging factor, offer diverse learning pathways through their engaging, interactive, and personalized features. These factors interact to jointly influence developmental trajectories, highlighting the importance of multi-dimensional and systemic support.

7.2. Summary of Effective Intervention Strategies

Based on the analysis of influencing factors, three intervention pathways are proposed: family, school-community, and digital. Family interventions should prioritize parent education and training, promote the scientific use of digital resources, and design playful yet educational mathematical activities. Schools and communities should collaborate to integrate age-appropriate mathematical guidance into early education curricula, organize parent-child math activities, and leverage community resources to support children's learning. Digital interventions should follow child-friendly design principles, develop effective digital games, and ensure the proper use of digital resources under parental guidance. The core of these strategies is to establish a collaborative network across family, school, community, and digital environments, providing children with comprehensive and sustained mathematical learning support.

7.3. Recommendations for Future Research and Practice

Future studies should address the limitations of cross-sectional designs by emphasizing longitudinal research and causal inference, utilizing multi-method and multi-source data to enhance scientific validity. Greater attention should be paid to cultural and individual differences through cross-cultural comparisons and the development of localized tools and interventions. In practice, multi-dimensional collaborative intervention models should be implemented with long-term tracking and evaluation mechanisms. Efforts should focus on ensuring educational equity for disadvantaged groups and enhancing the digital literacy of teachers and parents to improve their ability to identify and utilize high-quality digital resources, thereby fostering healthy early mathematical cognitive development.

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