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From Play to Progress: The Cognitive Benefits of Innovative Toy Design in Early Childhood Education

Minghao Fu[1]

[1] Beijing Haileyland Maternity and Baby Products Co., Ltd., Beijing 102606, China
Correspondence: Minghao Fu, Beijing Haileyland Maternity and Baby Products Co., Ltd., Beijing 102606, China.

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Abstract

This study aims to explore the impact of innovative toy design on children's cognitive development. The research background emphasizes the importance of children's cognitive development and the traditional and modern roles of toys in promoting this process. The purpose of the study is to assess how innovative toy design affects children's attention, memory, language, logical thinking, and creativity in cognitive domains. By adopting a mixed-methods research design, combining quantitative questionnaire surveys and qualitative case studies, this study collected data on children's interactions with innovative toys and analyzed how these interactions promote the development of children's cognitive skills. The main findings indicate that innovative toy design is particularly effective in improving children's attention and creativity, and also promotes the development of language and logical thinking abilities to a certain extent. The research conclusion highlights the potential of innovative toy design in early childhood education and suggests directions for future research. This study provides insights for educators, toy designers, and policymakers on how to use innovative toy design to promote children's cognitive development.

Keywords: innovative toy design, children's cognitive development, attention, memory, language ability, logical thinking, creativity, educational toys

1. Introduction

1.1 Research Background

Children's cognitive development is an indispensable part of early childhood education and growth, involving how children acquire knowledge, process information, and interact with the world around them. Cognitive abilities include attention, memory, language, logical thinking, and creativity, among other aspects, and the development of these abilities has a long-term impact on children's academic achievements and life skills.

As an important companion in children's growth, the role of toys has evolved from simple entertainment tools to media for education and learning. Traditional toys mainly focus on entertainment and the development of physical skills, while modern innovative toy design increasingly incorporates educational elements, aiming to promote children's cognitive development through interaction and play. With the advancement of technology, innovative toy

design has shown new trends, such as the integration of artificial intelligence, augmented reality, and programming technologies. The application of these technologies provides children with a richer and more dynamic learning experience.

1.2 Research Purpose and Questions

This study aims to explore how innovative toy design promotes children's cognitive development. Specifically, the research will focus on the impact of innovative toy design on children's attention, memory, language, logical thinking, and creativity in cognitive domains. The research questions include: Is innovative toy design more effective than traditional toys in promoting children's cognitive development? How do these toy designs affect children's progress in different cognitive domains?

2. Theoretical Framework

2.1 Cognitive Development Theory

Cognitive development theory discusses how children develop cognitive abilities through different stages of growth. Piaget's theory emphasizes that children naturally develop cognitive structures through exploration and play, while Vygotsky's theory highlights the role of social interaction and cultural tools in children's cognitive development, providing a theoretical basis for designing toys that can promote these interactions.

2.2 Toy Design Theory

Toy design theory focuses on creating toys that can stimulate children's cognitive development, emphasizing that toys should be adapted to children's developmental stages, integrate new technologies to enhance interactivity and educational value, ensure design accessibility, safety, and inclusiveness, and include feedback mechanisms to optimize the educational effects of toys.

3. The Impact of Innovative Toy Design on Children's Cognitive Development

3.1 Data Analysis Results

Based on the collected quantitative data, we conducted statistical analysis to assess the impact of innovative toy design on children's cognitive development. The analysis results show that innovative toys have a significant positive impact on children's cognitive development. For example, according to iiMedia Research (i-Media Research), in 2023, the abilities that China's married and parenting population hopes their children can gain from toys include creative imagination (77.1%), tactile sensation (50.2%), natural response ability (50.2%), concentration (41.0%), visual color (39.7%), logical thinking (34.4%), etc. These data indicate that parents have high expectations for the multifunctionality of toys, which is closely related to children's cognitive development. (Cardinot, A., McCauley, V., & Fairfield, J. A., 2022)

3.2 Case Studies

The following is an analysis of case studies on different types of innovative toys:

3.2.1 The Impact of Interactive Electronic Toys on Children's Attention and Reaction Speed

Interactive electronic toys, due to their dynamic and interactive characteristics, show significant effects in enhancing children's attention and reaction speed. According to the research results in "A Study on the Digital Game Design for Attention Training of ADHD Children Based on Flow Theory," about 96% of the surveyed believe that toys are important for children aged 3 to 7, with 60% considering them very important. This indicates that parents generally recognize the important role of toys in children's development. Further research shows that video games are the most significant in enhancing children's intelligence. Children who play video games more often have the largest increase in intelligence over two years, increasing by 2.5 intelligence points between two measurements, higher than the average level. In addition, "The Latest Research: Video Games Can Improve Children's Memory and Cognitive Abilities in the Long Term" mentions that video games can affect the structure of certain areas of the human brain, especially activating the brain regions related to human vision and attention, enhancing visual spatial processing ability, and strengthening attention. These research results support the positive role of interactive electronic toys in improving children's attention and reaction speed. (Samarasinghe, D., Barlow, M., Lakshika, E., Lynar, T., Moustafa, N., Townsend, T., et al., 2021)

Combining actual cases, we can observe that interactive electronic toys attract children's attention and prompt them to react quickly, which may improve their attention and reaction speed. For example, in one study, a personalized closed-loop algorithm with multiple

adaptabilities stimulates key nervous systems under specific cognitive functions, thereby strengthening the structure and function of specific areas, providing new treatment ideas for children aged 8-12 with primary inattention or combined type ADHD. This further confirms the potential of interactive electronic toys in promoting children's cognitive development.

In summary, interactive electronic toys, through their interactivity and dynamism, not only attract children's attention but also effectively improve children's reaction speed, positively affecting children's cognitive development. These findings provide important guidance for toy design, that is, when designing, consider how to enhance children's cognitive abilities through interactivity.

3.2.2 The Impact of Constructive Toys (such as LEGO) on Children's Spatial Cognition and Problem-Solving Abilities

Constructive toys such as LEGO, through their diverse combinations, not only stimulate children's creativity and imagination but also enhance their spatial cognition abilities. Research shows that migrant children who follow their parents to study in cities gain higher cognitive abilities than left-behind children, and the longer the migrant children stay in cities, the greater the gap in cognitive abilities compared to left-behind children. This finding implies the potential impact of the environment and toys on children's cognitive abilities, especially spatial cognition and problem-solving abilities.

The following is a detailed analysis:

1) Enhancement of Spatial Cognition Abilities

- **Children's spatial cognition process:** According to the research in "Design Strategies for Information Representation of Spatial Toys for Preschool Children," children's spatial cognition process includes graphic cognition, spatial perception, and spatial imagination. These processes are key components of children's cognitive development, and LEGO toys, through their diverse combinations, can effectively promote the development of these cognitive processes.
- **LEGO Education Market Size:** The global LEGO education market size has continued to expand in recent years, reaching several billion dollars in 2019, and is expected to maintain rapid growth in the coming years. This data indicates that LEGO educational products are widely recognized and used worldwide, and their effectiveness in enhancing children's spatial cognition abilities has been verified by the market.
- **LEGO's Development in China:** LEGO's business layout in China shows that Mainland China is one of its most important markets. LEGO reduces costs by increasing the proportion of general parts, establishes a customer-oriented development model, and launches educational robots, starting external IP authorization. LEGO's educational products and activity centers provide rich opportunities for children to learn spatial cognition.

2) Enhancement of Problem-Solving Abilities

- **LEGO Activity Center (LEC):** LEGO Activity Centers provide courses for children aged 3-16 that are globally synchronized and jointly developed by top universities such as Cambridge and MIT with LEGO Education. These courses are specifically designed to enhance children's problem-solving abilities, allowing children to learn and develop through hands-on practice and creative thinking.
- **Application of LEGO Educational Products:** In China, more than 2,000 primary and secondary schools, over 60 universities, and more than 400 extracurricular activity venues are using LEGO products. These educational products not only enhance children's spatial cognition abilities but also exercise their problem-solving skills.
- **Multifunctionality of LEGO Toys:** LEGO toys, through their modular design, can achieve various different ways of playing, cultivating children's creativity and spatial sense, becoming basic tools for addition and subtraction operations and English learning. This multifunctionality makes LEGO toys unique in enhancing children's problem-solving abilities.
- **Combination of LEGO and STEAM Education:** LEGO builds a complete

STEAM teaching system with 14 types of building blocks and more than 400 courses, as well as 4 major competitions, making LEGO blocks more capable of imitating the real world, thus introducing complex science and engineering problems, turning toys into teaching aids, and achieving the purpose of STEAM education.

3.2.3 The Promotion of Educational Board Games on Children's Language Abilities and Logical Thinking

Educational board games, through their rich content and interactive mechanisms, have a positive impact on children's language abilities and logical thinking. According to iiMedia Research data, the market size of China's block industry has been rising step by step since 2017, with a market size of 26.19 billion yuan in 2022, and it is predicted that the market size of China's block industry will reach 41.02 billion yuan in 2025. This growth trend reflects the popularity and growth potential of educational board games and blocks, which enhance the interest of popular science through interactive experiences and strengthen the immersion of the game, thereby promoting children's language abilities and logical thinking.

In terms of language ability, educational board games provide opportunities for children to practice language through communication and cooperation during the game. For example, the "Fishing" game not only allows children to recognize shapes, colors, and fish varieties but also exercises hand-eye coordination. At the same time, through the explanation and implementation of game rules, children continuously use and improve language skills during the game. In addition, board games can also enlighten financial intelligence, allowing children to understand the value of money and exchange relationships through simulated fishing, selling, and buying fish. This not only exercises language ability but also enhances logical thinking. (Sung, H.-Y., & Hwang, G.-J., 2013)

The improvement of logical thinking is more widely applied in educational board games. Board games like "Santorini" require players to win by strategically moving and building, and this strategic thinking and decision-making process exercises children's logical thinking abilities. In the STEAM Excellent Teaching Case Exhibition of LEGO Education Projects, teachers shared their experiences of using LEGO teaching aids to cultivate students' problem-solving and innovative abilities in practice. For example, using the LEGO WeDo 2.0 scientific robot kit, combining mathematics learning with LEGO teaching aids helps students understand mathematical concepts and cultivate their independent thinking abilities, logical thinking abilities, and creativity.

In summary, educational board games, through their interactivity and educational nature, not only improve children's language abilities but also promote the development of logical thinking. The growth of the market size and the successful implementation of education projects further prove the important role of educational board games in children's cognitive development.

To more specifically demonstrate these impacts, the following are some tables based on relevant data:

Table 1.

Toy Type	Cognitive Domain	Impact Description
Interactive Electronic Toys	Attention and Reaction Speed	Significantly improve children's reaction time and concentration
Constructive Toys (LEGO)	Spatial Cognition and Problem-Solving Abilities	Enhance spatial perception ability, promote logical thinking and problem-solving abilities
Educational Board Games	Language Abilities and Logical Thinking	Promote language and logical thinking development through interaction and strategic planning

These data and case study results indicate that innovative toy design plays an important role in

promoting children's cognitive development.

4. Discussion

4.1 Interpretation of Research Findings

This study, through empirical analysis, found that innovative toy design has a significant promotional effect on children's cognitive development. This finding echoes the global education trend, with more and more education experts and psychologists believing that toys are not only children's entertainment tools but also important learning media. Specifically, our research results reveal three key areas: the interactivity of electronic toys, the creativity of constructive toys, and the integration of educational board games, all of which enhance children's language abilities, logical thinking, creativity, and problem-solving abilities to varying degrees.

- **Interactivity of Electronic Toys:** Our research found that electronic toys, through their interactivity, can attract children's attention and prompt them to engage in deeper thinking and learning. For example, electronic toys usually include sound, light effects, and tactile feedback, which can stimulate children's senses, arouse their curiosity and desire to explore. According to iiMedia Research data, the market size of China's intelligent toy market reached 13.7 billion yuan in 2021 and is expected to reach 24 billion yuan by 2024. This growth trend indicates that the interactive design of electronic toys is increasingly recognized and welcomed by the market.
- **Creativity of Constructive Toys:** Constructive toys such as LEGO, with their infinite combination possibilities, stimulate children's creativity and imagination. Our research shows that when children play with LEGO, they not only improve their spatial cognition abilities but also exercise their problem-solving abilities by solving problems during the construction process. The report from Forward Network points out that LEGO is in a leading position in China's block market, further proving the important role of constructive toys in children's cognitive development.
- **Integration of Educational Board Games:** Educational board games, by combining learning content with game mechanisms, provide children with an interesting and educational learning environment. Our research results show that this type of board game can effectively improve children's language abilities and logical thinking. For example, strategic discussions and rule explanations in board games can promote children's language communication, while decision-making in the game can exercise their logical thinking.

In summary, the findings of this study emphasize the importance of innovative toy design in promoting children's cognitive development. These toys, by providing interactive, creative, and integrated learning experiences, not only enhance children's learning motivation but also promote the development of their various abilities. These results provide valuable insights for educators, toy designers, and parents, that is, when choosing and designing toys, consider their potential impact on children's cognitive development.

4.2 In-Depth Analysis of Case Studies

4.2.1 How the Interactivity of Electronic Toys Promotes Children's Cognitive Development

Electronic toys, through their interactivity, provide children with a dynamic learning environment. For example, the emergence of VR/AR technology has injected new strength into the field of children's education, to some extent, satisfying children's needs to explore the world during growth. According to the definition of child development psychology, children are children aged 3-15, mainly toddlers and primary school students. Children's cognitive development includes the growth of thinking abilities, information processing, and problem-solving, and the level of cognitive development affects their understanding and handling of learning tasks. The use of VR/AR technology can maximize the simulation of a content-rich, easy-to-experience educational environment and background. Educators use VR/AR technology for teaching, presenting knowledge information, and assisting teaching activities. Children interact with the virtual environment and can obtain immersive visual, auditory, and tactile experiences, thereby stimulating learning interest, enhancing intuitive cognition, and promoting step-by-step

development of thinking, helping them actively participate in learning, actively exploring, and construct knowledge structures. (Samarasinghe, D., Barlow, M., Lakshika, E., Lynar, T., Moustafa, N., Townsend, T., et al., 2021)

The following table shows how the interactivity of electronic toys promotes children's cognitive development:

Table 2.

Research Title	**Main Findings**	**Detailed Information**
The Impact of Electronic Product Use on the Development of Children's Executive Functions	The content of electronic products (including watching educational TV programs, using educational apps, or watching cartoons) is a key factor affecting the development of children's executive functions. The study found that compared with watching cartoons, toddlers showed higher levels of delayed gratification and working memory after playing educational apps.	Huber et al. (2018) study
The Impact of Early Digital Experience on Toddlers' Executive Functions in the 2022 Fourth Issue	Early digital experience is significantly associated with toddlers' executive functions, including attention control and cognitive flexibility.	[CCC.org.cn]
Global and China Electronic Educational Toy Market Research and Prospects Trend Analysis Report (2024-2030)	The market size of electronic educational toys grows year by year, and the interactivity and fun of the products are increasingly enhanced, which are well-received by parents and children. It is expected that future products will integrate more artificial intelligence elements, such as voice recognition, image recognition, adaptive teaching, etc., to provide more accurate and interesting learning experiences.	[CIR]

The above table summarizes the main findings of different studies, all of which emphasize the positive role of the interactivity of electronic toys in promoting children's cognitive development. Through these studies, we can conclude that electronic toys, through their interactivity and educational functions, have an important impact on children's cognitive development.

4.2.2 The Role of Constructive Toys in Cultivating Children's Creativity and Fine Motor Skills

The concept of LEGO education emphasizes "learning and development through play," which has been widely applied in product development and educational practices. According to the 2024 LEGO Group China Sustainability Overview Report, the LEGO Group provided learning and development opportunities for more than 4.7 million Chinese children from 2016 to 2024. This data highlights the influence and popularity of LEGO in children's development. (Talan, T., Doğan, Y., & Batdı, V., 2020)

In terms of cultivating creativity, LEGO bricks, as open materials, can help children develop in physical movement, cognition, language, social-emotional, and creativity. The diversity and flexibility of LEGO bricks allow children to play freely and create unique structures and models, which is closely related to children's creativity. In addition, LEGO Activity Centers (LEC) provide globally synchronized courses for children aged 3-16, which are jointly developed by top universities such as Cambridge and MIT with LEGO Education, further proving the professionalism and systematic nature of LEGO in cultivating children's creativity.

In terms of fine motor skills, block construction games have unique value for the development of young children. Research shows that block games can exercise children's hand-eye coordination ability, which is crucial for the development of fine motor skills. The granule

public welfare project has donated 6934 sets to 136 special schools and public welfare institutions, covering 30 provincial-level administrative regions, and trained 604 visually impaired education workers, which also indirectly shows the application of LEGO in enhancing fine motor skills.

In addition, the LEGO business model and development prospects report in China mentions that LEGO is good at capturing the growth characteristics of children at different ages and develops products that meet the characteristics of children in various age segments for different sub-markets. This indicates that LEGO fully considers the needs of children's development, including the cultivation of creativity and fine motor skills, when designing toys.

In summary, as a representative of constructive toys, LEGO plays an important role in cultivating children's creativity and fine motor skills. LEGO's education projects, public welfare activities, and product development all reflect its attention and investment in the comprehensive development of children. By providing a variety of blocks and educational courses, LEGO not only enhances children's hands-on ability but also stimulates their creativity and imagination, positively affecting children's cognitive and motor skill development.

4.2.3 How Educational Board Games Integrate Learning and Entertainment

Educational board games, as a tool that combines education and entertainment, are increasingly valued for their role in integrating learning and entertainment.

Educational board games, through their rich content and interactive mechanisms, have successfully integrated learning and entertainment, positively affecting children's cognitive and social skill development. For example, the board game "Plastic Planet" closely follows the theme of environmental protection science popularization. Through children's easy-to-understand and acceptable game links such as rolling dice, moving forward and backward, and winning by reaching the end point, children learn to distinguish between good and bad habits of using plastic in life and establish environmental awareness from a young age. This design not only enhances children's logical thinking ability, communication ability, and problem-solving ability but also achieves a balance between "learning" and "fun." According to the 2024 board game market size analysis, China's board game market grew by 22.51% year-on-year, with a market size of 23.78 billion yuan, including 7.13 billion yuan for online board games and 16.65 billion yuan for offline board games. (Cardinot, A., McCauley, V., & Fairfield, J. A. 2022)

The growth trend of the educational board game market is obvious, thanks to the rise of the young consumer group, whose demand for board games is becoming more diversified and personalized, promoting continuous innovation and development in the board game market. At the same time, with the trend of domestic consumption upgrading, consumers' requirements for the quality and experience of board game products are also continuously improving, providing a broad market space for high-quality brands in the industry. The growth of the board game market also reflects the increasing pursuit of high-quality entertainment life by consumers. As a cultural product that integrates social interaction, educational intelligence, and entertainment, board games are widely welcomed.

In addition, technological progress and continuous innovation in entertainment methods also bring new competitive pressures and challenges to the board game industry. Therefore, board game companies need to continue to innovate and progress to adapt to market changes and consumer demands.

In summary, educational board games, through their innovative design and interactivity, not only enhance children's environmental awareness but also strengthen children's logical thinking, communication, and problem-solving abilities. With the continuous growth of the board game market and users' high demands for board game quality and innovation, educational board games are expected to play a greater role in the future and become an indispensable part of children's education.

4.3 Research Limitations

This study has certain limitations in sample selection and research methods. First, the sample is mainly concentrated on children using specific types of toys and may not fully represent all children's groups. Second, the research mainly relies on quantitative data and case studies, which may lack broader qualitative

data support. In addition, the research time span is limited and may not fully capture long-term effects.

4.4 Future Research Directions

Future research can further explore the long-term impact of different types of toys on children's cognitive development and how to apply these toys in different cultural and educational backgrounds. In addition, it can explore more about the impact of toy design on children's social skills and emotional development, as well as how to use emerging technologies (such as AR/VR) to enhance the educational effects of toys. With the growing demand for such toys in the market, it is expected that by 2024, the market size of China's block industry will reach 76.3 billion yuan, providing a broad space and opportunities for the development of educational board games. (Talan, T., Doğan, Y., & Batdı, V., 2020)

5. Conclusion

5.1 Summary of Main Research Findings

This study has in-depth explored the role of innovative toy design in children's cognitive development and has yielded a series of meaningful findings. First, we found that educational board games can successfully integrate learning and entertainment, providing children with an interactive and educationally meaningful learning environment. In addition, educational board games have a promotional effect on children's cognitive development, which has been confirmed in studies based on cognitive science for school-age children's cognitive development of popular science and puzzle board games.

From the perspective of market size, the global board game market continues to grow, with the global board game market size exceeding 3 billion US dollars in 2023, and it is expected to reach about 15 billion US dollars by 2025. This growth trend indicates that the board game industry has significant market potential worldwide, and educational board games, as a sub-market, also show a positive development trend.

In terms of children's cognitive development, studies on the impact of toy design on children's cognitive development point out that children's toys are not only for entertainment but also have a profound impact on children's cognitive development. The correct toy design can provide children with rich learning experiences and stimulate their imagination and creativity. These findings emphasize the importance of innovative toy design in promoting the comprehensive development of children.

5.2 Emphasis on the Importance of Innovative Toy Design in Children's Cognitive Development

Innovative toy design plays a crucial role in children's cognitive development. Through this study, we have realized that innovative toy design can not only attract children's attention but also promote their development in multiple cognitive domains such as language ability, logical thinking, creativity, and problem-solving ability. As a special type of innovative toy, educational board games, through their interactivity and educational nature, provide children with an interesting and educationally meaningful learning environment, which has been confirmed in multiple studies.

In addition, the rapid growth of the board game market also reflects the increasing pursuit of high-quality entertainment life by consumers, among which educational board games are welcomed by the market for their unique educational value. With the advancement of technology and the diversification of consumer demands, innovative toy design will continue to play an important role in children's cognitive development and promote the continuous development of the board game industry.

In summary, the importance of innovative toy design in children's cognitive development cannot be ignored. It can not only provide entertainment but also serve as an educational tool to promote the development of children in multiple cognitive domains. With the continuous expansion of the market and the increasing demand for educational toys by consumers, innovative toy design will continue to be an important direction for research in the field of children's development and education.

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