

DESIGN AND DEVELOPMENT OF A MULTI-GAME EDUCATIONAL TOY FOR COGNITIVE DEVELOPMENT OF CHILDREN

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Abstract : Play-based learning plays an important role in enhancing children's cognitive abilities by encouraging active participation, creativity, logical reasoning, and problem-solving. However, most educational toys available today are designed for a single activity, limiting long-term engagement and requiring parents to purchase multiple toys to support different learning outcomes. This study presents the design and development of a multi-game educational toy for children aged 6-8 years that combines multiple learning activities within a single transformable product to provide an engaging, reusable, and cost-effective learning experience.

A user-centered design methodology was adopted, involving literature review, market research, product benchmarking, questionnaire surveys, Quality Function Deployment (QFD), Product Design Specification (PDS), concept development, prototyping, and user evaluation. The final prototype integrates interchangeable magnetic game modules that promote memory, logical thinking, creativity, problem-solving, and fine motor skills while encouraging collaborative play. The findings indicate that a modular multi-game toy can improve user engagement and support cognitive development while offering a practical alternative to conventional single-purpose educational toys.

IndexTerms - Educational toy, Play-based learning, Cognitive development, Product design, Modular design, User-centred design.

1.INTRODUCTION

Play is an important part of children's learning and cognitive development, supporting creativity, problem solving, logical thinking and memory through active participation. Educational toys provide an interactive learning experience that makes learning fun while also developing the required cognitive skills (Piaget, 1952; Hirsh-Pasek et al., 2009).

Educational toys come in a wide range, but most products concentrate on a single activity or learning objective. Most children get bored with repetitive play quickly. Parents often have to buy a number of toys to cover different learning areas. This increases cost, storage requirements and long term engagement. This highlights the need for a multifunctional educational toy that combines different learning experiences in a single compact product.

In response to this need, this study introduces the design and development of Discovery Dome, a transformable multi-game educational toy for children aged 6-8 years. The toy is designed to combine a range of educational games in a portable and modular design to support vocabulary, math skills, memory, colour recognition and problem solving through play-based learning. The final product was developed using a user-centered design approach, including literature review, user research, requirements analysis, concept development, prototyping and evaluation.

1.1 Need for the Study

Educational toys have become popular, but most of today's products focus on one activity or learning goal. Once children have learned how to do something, they lose interest in the activity, which reduces the educational value of the toy. Parents are also forced to buy different toys to help with different aspects of learning, which means costs are higher and more storage is needed. While previous research done by people focused on developing educational boards, LEGO-based learning, smart toys, and multifunctional teaching aids, limited attention has been given to the development of a multifunctional educational toy that combines several learning activities into one product, and which focuses on different areas of cognitive development in children. This provides an opportunity to develop a toy that provides a wider range of educational experiences, while being small, reusable, and fun.

2. RESEARCH METHODOLOGY

A user-centered design methodology was used to develop the proposed multi-game educational toy for children aged 6–8 years old. The study was carried out in a systematic sequence of stages including literature review, market research, user research, requirement analysis, concept development, prototype development and evaluation. Table 1: Summarized Research Methodology. The table below describes the methodology used at each stage and the objectives for each method.

Table 1. Summarized Research Methodology

Research Stage	Method Used	Purpose
Literature Review	Research papers, journals, and books	To understand play-based learning, cognitive development, and educational toy design.
Market Research	Product benchmarking and competitor analysis	To identify existing products, market trends, and design opportunities.
User Research	Questionnaire survey and user interactions	To identify user needs, preferences, and challenges.
Requirement Analysis	Quality Function Deployment (QFD) and Product Design Specification (PDS)	To convert user requirements into design specifications.
Concept Development	Brainstorming, sketching, and concept evaluation	To generate and select the most suitable design concept.
Prototype Development	CAD modelling and physical prototyping	To develop a functional prototype of the selected concept.
Evaluation	User feedback and usability testing	To assess functionality, usability, and educational effectiveness.

2.1 Literature Review

A literature review was undertaken using research papers related to play based learning, cognitive development, educational toy design, LEGO based learning, board games and multi-functional educational toys. The reviewed studies showed that active participation in play-based learning improves memory, creativity, logical thinking, problem-solving and language development of children (Kohli, 2025; Kausar et al., 2024). LEGO-based activities and board games were found to support spatial reasoning, mathematical skills, memory, decision-making, and collaborative learning (Al Ayyubi et al., 2025; Ulkhatiata & Purnama, 2023; Wang & Hung, 2010; O'Neill & Holmes, 2022). The literature also stressed that educational toys need to develop fine motor skills, meaningful interaction, and long-term engagement by merging multiple learning activities into one product (Bahri, 2023; Kara & Çağıltay, 2020; Chaung et al., 2023; Astuti et al., 2022). These findings informed the design requirements and development of the proposed Discovery Dome.

2.2 Product and User Research

A product and market study was performed to understand the existing educational toys and the possible innovation opportunities. Product benchmarking was conducted with the assistance of educational toys of LEGO, Smartivity, Funskool, Skillmatics and Imagimake [LEGO (2026), Smartivity (2026), Funskool (2026), Imagimake (2026)]. The study examined educational value, number of activities, portability, safety, durability, materials and cost. The findings revealed that most of these products are designed around a single activity or limited gameplay, but they support specific learning objectives, underscoring the need for a more flexible and reusable educational toy.

An online questionnaire survey was conducted with 114 respondents including parents, teachers and people familiar with children's learning behaviour to understand the needs of the users. The questionnaire was designed to explore the skills that parents expected from educational toys, whether they preferred single-game toys or multi-game toys, the challenges that parents faced with existing toys, preferred toy features, and suggestions for improving children's educational toys. Moreover, 20 semi-structured interviews were conducted with parents of children aged 6–8 years from different professional backgrounds and school teachers. A strong preference was shown for educational toys that combine multiple learning activities, remain engaging over time, are compact, interactive and easy to store. These findings directly contributed to design requirements and development of the proposed educational multi-game toy. Figure 1 shows one of the interview sessions with a parent.



Figure 1 Interview

2.3 Key Insights from User Study

Parents and teachers preferred educational toys that were engaging, safe, durable, portable and able to support multiple learning activities according to the survey and interviews. Participants further pointed out the importance of a compact, multi-game educational toy that would encourage long-term engagement and cognitive development, since children quickly lose interest in single-purpose toys. Parents preferred toys that are still easy to use and easy to store, but that encourage independent learning. The teachers also emphasized the importance of play-based activities to develop vocabulary, logical thinking, mathematical skills, memory and problem-solving rather than repetitive learning methods. These findings informed product requirements and guided the development of a transformable educational toy that integrates multiple learning experiences in a single product.

2.4 Requirement Analysis

The outcomes of literature review, product study, questionnaire survey and user interviews were translated into design requirements by using Quality Function Deployment (QFD) and Product Design Specification (PDS). QFD was helpful for prioritizing user requirements by identifying the links between customer needs and product characteristics, and PDS specified the technical and functional requirements for the toy being suggested. The analysis identified the key design requirements to be educational value, multiple learning activities, child safety, durability, portability, ease of use, attractive appearance, compact storage and affordability. These requirements were used as benchmarks throughout the product design and concept development process.

3.DESIGN AND DEVELOPMENT

The multi-game educational toy proposed was designed and developed using the user-centered design approach. Based on the results of the literature review, market research, product benchmarking and user surveys, the design process highlighted the need for an educational toy that is entertaining, multipurpose, portable and can support various aspects of cognitive development. These findings resulted in the development of key design requirements such as educational value, safety, ease of use, durability, portability and long-term engagement that guided the development of the product. We brainstormed and sketched to generate multiple concepts to explore different product configurations and learning mechanisms.

Each concept was evaluated based on its functionality, educational effectiveness, ease of interaction, manufacturability, and suitability for children aged 6–8 years. After comparing all, six were selected to make detailed concept sketches. Few of the sketches are shown in Fig. 2.

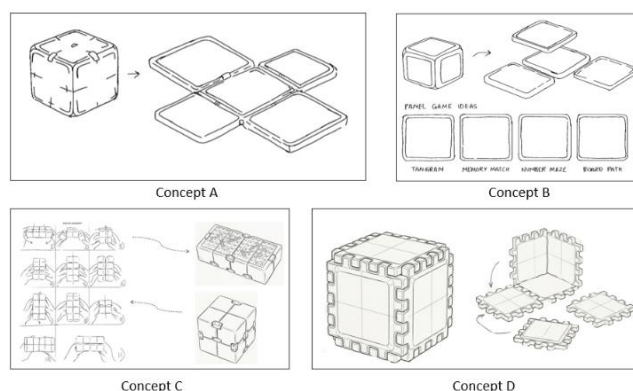


Fig 2 Concept sketches

After the first concept exploration, four concept sketches were shortlisted for further evaluation. The concepts were assessed against the design requirements from the QFD and Product Design Specification (PDS). Based on their functionality, educational value, transformable mechanism and overall feasibility three concepts were selected for detailed CAD modelling and high quality rendered visualisation as shown in Fig. 3.

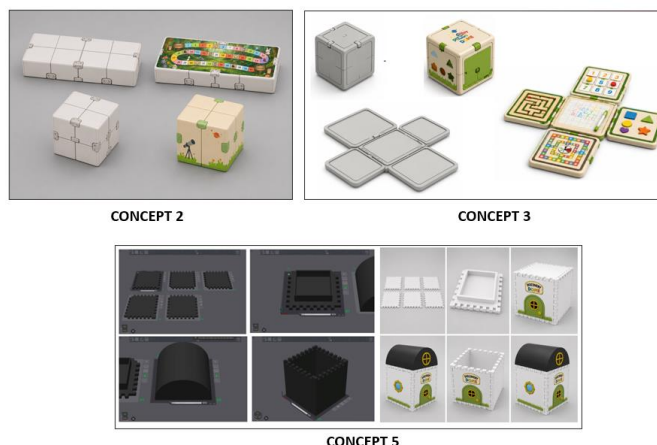


Figure 2 Selected concepts developed as CAD & rendered model

The three concepts rendered were further reviewed for the selection of the most appropriate design to prototype. Two concepts were selected for the study model development based on structural feasibility, ease of fabrication, transformable mechanism and overall user interaction. These study model were fabricated to evaluate the product form, ergonomics, functionality, and usability before the design finalization. The study model developed for evaluation is shown in Fig. 4.



Figure 3 Study models of selected concepts

The low-fidelity prototypes were evaluated using a Pugh matrix and in a concept evaluation with nine participants including parents, teachers and children. The concepts were evaluated on the basis of ease of use, educational value, functionality, portability, aesthetics, and overall user preference. Table 2 presents the concept evaluation matrix. The evaluation results showed that Concept 5 received the highest overall score and was chosen to be enhanced and developed into the final prototype.

Table 2 concept evaluation results

Criteria	Concept C	Concept D
Visual Appeal	9	9
Uniqueness	8	9
Ease of Understanding	9	8
Ease of Access to Games	9	9
Child Friendliness	9	9
Safety Perception	9	9
Storage & Organization	8	9
Interactive Opening Mechanism	9	10
Overall Preference	9	9
Total Score	79	81
Rank	2	1

The concept evaluation led to the choice of Concept 5 for the development of the final prototype. The dimensions of the product were determined by taking into account the anthropometric requirements of children of 6-8 years of age, which guarantees

portability, easy handling and comfort to the user. The final design is a 16×16 cm transformable cube with a 1cm gap on all four sides for the puzzle-hinge mechanism, enabling the cube to be smoothly unfolded into various interactive play surfaces while maintaining the structural stability. The design features an integrated storage compartment and a removable magnetic dome. Fig.5. The final fabricated prototype is shown.



Fig 5 Final fabricated prototype

The final prototype, called the Discovery Dome, combines three educational games that aim to develop different areas of children's cognitive development through play. The name Discovery Dome came from the concept of children discovering new concepts and developing their cognitive development by engaging with the toy Discovery Dome. When unfolded the toy opens into cross panels. In which the game Word Adventure spread across the three connected center panels and the other two games placed on the side panels, as shown in Figure 6. Word Adventure is played on the three center panels of the opened toy. Children take two alphabet cards from a deck and use the letters shown to think of a meaningful word. If they successfully say a correct word within 10 seconds, they move one step forward on the game board. The first player to reach the finish wins the game. This activity helps children improve vocabulary, spelling, word formation, language skills, quick thinking, and concentration. Figure 7 shows the Word Adventure game. Detective Dot Hunt is played on the single lower panel, which has three levels, addition board attached to the panel and two magnetic attachment one is a subtraction board and other one is a multiplication. The kids have to roll two dice and calculate according to the board selected, and find the number of dots as found in the calculated answer with a magnifying glass. By combining math with observation, the game develops numerical skills, logical thinking, problem-solving, visual attention, and concentration. Figure 8 shows the Detective Dot Hunt game. Milo's Missing Clothes is played on upper single panel, each child picks a character card showing Milo the cute monster dressed in different coloured clothes. The card is shown for 3 seconds and then turned over, and the child must remember the clothes. The board has nine coins turned upside down and each kid on their chance can turn the coin and if it is their wanted coloured cloth they can keep it if not they have to place it back again upside down, on the other kid's chance if the coin turned by previous kid was the coloured cloth they wanted they can remember the coin's place and take it if not they can turn some other. The player who correctly completes Milo's outfit wins the round. This game improves memory, colour recognition, visual observation, attention to detail, and recall skills. Figure 9 shows Milo's Missing Clothes game. The completed prototype was then assessed for its usability, functionality and effectiveness in assisting cognitive development in children aged 6–8 years.



Figure 6 Opened configuration of the toy



Figure 7 Word Adventure



Figure 8 Detective Dot Hunt



Figure 9 Milo's Missing Clothes

4.RESULTS & DISCUSSION

The fabricated prototype of Discovery Dome was evaluated with children aged 6–8 years in the presence of their parents to assess its usability, functionality, and overall user experience. The evaluation focused on parameters including ease of handling, engagement, game interaction, portability, safety, and educational value. User testing of the developed prototype is shown in Fig. 10, while the evaluation observations are summarized in Table 3.



Figure 10 Kids playing with Discovery dome

Table 3 Prototype evaluation observations

Evaluation Criteria	Observation
Ease of handling	Children were able to comfortably hold and use the toy.
User engagement	Multiple games maintained children's interest during play.
Game interaction	Children interacted with the activities with minimal guidance.
Portability	Parents found the product compact and easy to carry.
Educational value	The games encouraged language, mathematics, memory, and colour recognition skills.

The evaluation indicated that the transformable design and modular game arrangement provided an engaging learning experience for children. The puzzle-hinge mechanism allowed the toy to be opened and closed smoothly, while the magnetic game panels were easy to assemble and interchange. Parents appreciated the compact design and integrated storage compartment, whereas children showed interest in exploring different games within a single product.

The findings suggest that **Discovery Dome** successfully addressed the major design requirements identified during the research phase, including portability, ease of use, safety, educational value, and long-term engagement. By integrating vocabulary, mathematics, memory, and colour recognition activities into one transformable educational toy, the product offers a practical play-

based learning solution for children aged 6–8 years. Although the prototype was evaluated with a limited number of users, the feedback indicates that the proposed design has the potential to support cognitive development through interactive learning.

5.CONCLUSION

This study presented the design and development of Discovery Dome, a transformable multi-game educational toy designed to support the cognitive development of children aged 6–8 years through play-based learning. A user-centred design approach involving literature review, user research, QFD, PDS, concept development, prototyping, and evaluation guided the development of the final product. The toy integrates multiple educational games within a single compact and transformable design, promoting vocabulary, mathematical skills, memory, and colour recognition. User evaluation indicated that the prototype was engaging, easy to use, and appropriate for the target age group while meeting the key design requirements identified during the research. Future work may focus on incorporating additional game modules and conducting larger-scale user studies. Overall, the proposed design demonstrates the potential of transformable educational toys to make learning more engaging, interactive, and meaningful for children.

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