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SUSTAINABLE DEVELOPMENT IN DESIGNING CHILDREN'S FURNITURE: TECHNIQUES AND TOOLS

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*Abstract**. The purpose** of this study is to develop multifunctional furniture that meets the evolving needs of children through sustainable design methods. It aims to drive the development of children's furniture design towards sustainability, reducing environmental impact, while providing children with a healthier, more flexible, and personalized environment for growth.*

***Methodology.** Literature analysis method: Referencing monographs and journals both domestically and internationally on children's furniture design and sustainable design. Interdisciplinary research method: Involving the integration of theories and methods from different disciplines to delve into the sustainable design techniques for children's furniture. Case analysis method, structural-functional analysis, etc. are used.*

***The research results** highlight the effectiveness and practicality of the sustainable design techniques for children's furniture. Through foldable and stackable structures, adjustability in furniture dimensions has been successfully achieved, enabling the furniture to adapt to the changing body sizes and usage needs of children. Addressing children's physiological characteristics to support their healthy growth and reduce fatigue, adjustable-angle furniture has been designed for desks and chairs. Implementation of modular design allows for furniture reconfiguration and functional expansion as children grow, enhancing both the fun and educational aspects of the furniture, encouraging children's participation and exploration. Application of color variability technology, through detachable decorative panels, allows for personalized adjustments of furniture colors according to children's preferences and psychological needs. The study also achieves design standardization, including standardization of components and interfaces, which not only enhances furniture replaceability and maintainability but also optimizes resource utilization, reduces production costs, and minimizes environmental impact.*

***Scientific novelty.** The innovation lies in the integration of adjustable, modular, and intellectually stimulating multifunctional furniture. This technological approach particularly considers the physiological and psychological growth needs of children, supporting their healthy development through adjustable angles and dimensions. Additionally, the introduction of color variability technology allows children to change*

the appearance of the furniture according to their personal preferences, enhancing its customization and interactivity.

The practical significance *of the obtained results lies in the possibility of their application for designers and manufacturers in the design of children furniture.*

Keywords: Children's Furniture, Sustainable Design, Technology Pathway, Furniture Design, Multifunctional Furniture, Design principles.

INTRODUCTION

This study focuses on the challenges currently faced by children's furniture design. Traditional furniture often lacks the flexibility to adapt to children's growth changes, leading to frequent replacements that not only increase the economic burden on families but also result in resource wastage. Meanwhile, with increasing societal emphasis on environmental protection and sustainable development, higher demands are placed on the environmental performance and sustainability of furniture products. To address these issues, the research proposes a series of innovative children's furniture design techniques aimed at achieving sustainable use, adaptability, entertainment, and educational value through methods such as adjustable dimensions, angle variations, modular design, color variations, and standardized design. These innovations aim to meet the needs of children's growth while reducing environmental impact and promoting the sustainable development of the furniture industry.

ANALYSIS OF PREVIOUS RESEARCHES

Author Phuah Z. Y. et al. research aims to conceptualize creative and reusable children's furniture. The invention can serve as accessories for children's furniture such as cribs, high chairs, bed rails, and chairs. While retaining many additional values of reusability, the invention prolongs the lifespan of furniture, reducing consumer expenditure costs and saving space [5]. Wu Q. et al. studied the sustainable design of children's beds, combining modular design theory to address the lifecycle issues of children's beds, better meeting children's usage needs [14]. Author Salvador C. through a case study of 10 models of children's high chairs, provided direction for material selection and surface treatment for children's high chair projects, making them more suitable for children and sustainability [6]. Author Xiong X. et al. conducted standardized experimental research on children's solid wood furniture parts using grouping technology [8]. Author Phuah Z. et al. proposed five concepts. These concepts were evaluated to determine which one best met 11 improvement requirements, including improved aesthetics, cost, simplicity, manufacturability, functionality, comfort, ease of reuse, durability, safety, sustainability, and creativity. The invention can be used as cribs, high chairs, bed safety rails, chairs, pull-up bars, walkers, and toilet accessories [5].

Authors Gumulya, D., & Andriato, T. D. based on case studies of designing children's furniture for schools, aimed to develop a framework to guide designers in integrating ecological design strategies into the framework of design thinking [3].

Authors Ye, J., Li, W., Yang, C. applied scenario theory to the design of modular children's furniture, which effectively helps designers grasp the relationship between products and users and their needs more accurately, further improving product rationality and satisfaction, and providing new effective explorations for modular children's furniture design [9]. Authors F. Tavşan et al. believe that furniture can serve as a gaming tool as it can be used at different stages of children's ages and can serve as a gaming tool [7]. Authors, combining the contradiction analysis of TRIZ (Theory of Inventive Problem Solving) theory, constructed a product innovation design process based on TRIZ theory. Then, effectively using TRIZ tools to solve problems, they improved children's chair furniture design to achieve the optimal solution [15].

From previous research, sustainable design of children's furniture needs to consider multifunctionality, modularization, material selection, standardization, ecological design strategies, understanding of user needs, entertainment, and innovative design processes. These factors combined can create furniture products that not only meet the needs of children's growth but also have cost-effectiveness, safety, and environmental friendliness.

STATEMENT OF THE PROBLEM

In the field of sustainable design for children's furniture, although previous research has proposed innovative concepts such as multifunctionality, modular design, material optimization selection, standardized production, and ecological design strategies, translating these ideas into concrete and feasible technical pathways

still poses challenges. Additionally, there is a need for summarizing and articulating these technical pathways.

RESULTS OF THE RESEARCH

Conventional children's furniture often overlooks the need for designing according to different stages of children's development. Consequently, after fulfilling specific functions for a particular stage, the furniture may lose its relevance. Parents are also unlikely to purchase new furniture for their children for each developmental stage, necessitating the extension of furniture functionality. Extendable methods primarily involve structurally sound designs, allowing for adjustments in dimensions and heights to expand the furniture's original functions. While retaining its original functions, these adjustments further extend and prolong the furniture's usability, thereby extending the lifespan of children's furniture.

Adjustable specification size technology. Through innovative "folding" designs, it's possible to achieve flexible expansion of children's furniture dimensions. This design ingeniously transforms a portion of the furniture, whether smaller in area or volume, into a larger space or volume through folding mechanisms [4]. Conversely, when space-saving is necessary, larger objects can be folded into compact forms. This design concept is applicable not only to traditional wooden materials but also to metal, PP plastic, environmentally friendly materials, and even paper materials, offering infinite possibilities for sustainable design and use of children's furniture.

"Folding" technology is mainly divided into two forms: "foldable" and "stackable". In "foldable" design, various innovative folding structural methods are employed, with the most common being riveted or bolted connections between components [1]. The advantage of this design lies in the ease of disassembly provided by bolted structural components, facilitating storage and transportation. The design of folding structures is clever, typically involving two or more folding connection lines, each line allowing for different distances and numbers of folding points. Importantly, the total distance between these folding points must be equal to the length of the connecting line to ensure smooth folding and unfolding of the furniture. This design is particularly suitable for desks and beds, allowing for flexible adjustments in usage range through extension panels to meet diverse usage needs. Furthermore, through folding structures, slight adjustments to furniture components can change their usage functions, enhancing the furniture's versatility. (Fig. 1, a) "Stackable" design involves stacking multiple identical units of furniture together, saving space and facilitating storage and transportation. The more reasonable the design of stackable furniture, the more units can be stacked. This design is particularly common in chair-type furniture. During design, emphasis should be placed on achieving the basic function of "stacking" to maximize space utilization. (Fig. 1, b). The focus of this study is on sustainable design for children's furniture, primarily achieved through "foldable" design to facilitate flexible changes in size and function, adapting to the continuously changing needs of children's growth process.

To ensure the sustainability of children's furniture and meet the growing needs of children, adjustable functionality for seat and desk height is a crucial design consideration. This adjustment can typically be achieved through several methods: fixed-position (Fig. 2), hand-crank (Fig. 3), wire-controlled (Fig. 4, a), and hydraulic. Taking hand-crank children's chairs as an example, users can easily adjust the chair's height by turning the handle to accommodate children of different heights. Wire-controlled chairs, on the other hand, usually require checking the bottom of the seat where the manufacturer provides hydraulic buttons or levers (Fig. 4, b), enabling precise height adjustment through simple operation.

In the design of children's wardrobes, the exterior dimensions can be planned according to the standards of adult wardrobes to achieve visual harmony and consistency in furniture. The internal structure of the wardrobe must possess a high degree of adjustability to accommodate the changing height and storage needs of children as they grow. For preschool-aged children, designers should consider low-height wardrobe structures, utilizing components such as partition bars, wardrobe crossbars, and locating pins to achieve adjustable wardrobe crossbars. Rational partitioning of internal functional areas based on the child's height characteristics enhances convenience and safety of use (Fig. 5). As children gradually grow, the original wardrobe can be reconfigured internally to flexibly adapt to new usage requirements, transforming into storage space suitable for teenagers or adults. Using components such as partition bars, partition supports, and layer support panels achieves shelf adjustment (Fig. 6). This design strategy not only promotes long-term furniture use but also reduces resource consumption associated with the frequent need for furniture replacement as children grow, demonstrating the sustainability of children's furniture design.

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a

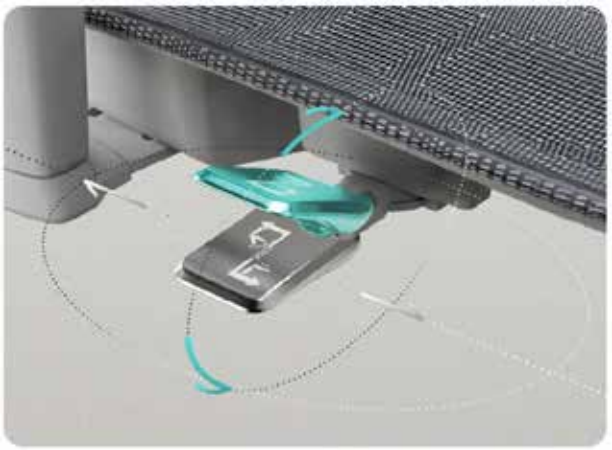
b

Fig. 1. Folding furniture: a – flip-flop furniture, China, 2024; b – stacked furniture, China, 2024

Fig. 2. Positioning Child Seat, China, 2024

Fig. 3. Hand-operated study table, China,2024

a



b

Fig. 4. Seat by wire: a – In-line structure, China, 2024; b – toggle paddle by wire, China, 2024

Fig. 5. Wardrobe Crossbar Adjustment, China, 2024

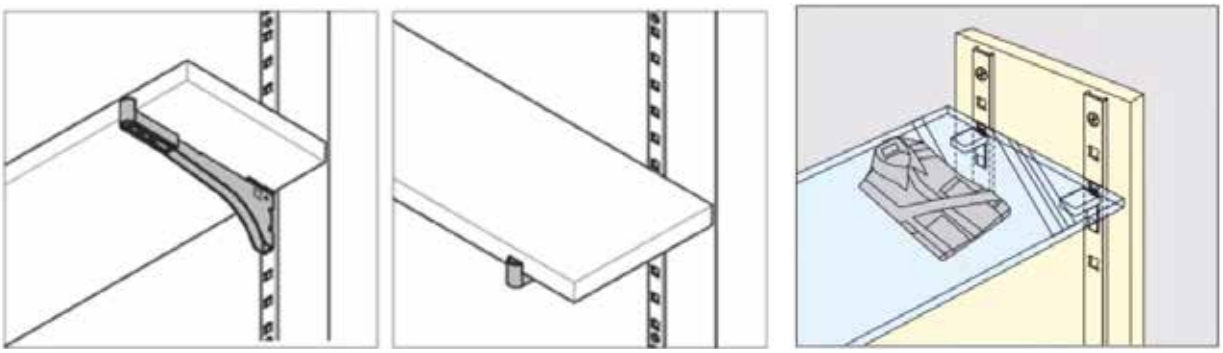


Fig. 6. Wardrobe interior cross-panel approach, China, 2024

Adjustable angle technology. After a thorough analysis of the physiological growth characteristics of children aged 3-12, it is recognized that although the skeletons of children in this age group are relatively sturdy, the ossification process is not yet complete, making them susceptible to deformation. Additionally, children's neural cells are fragile and prone to fatigue. Considering these physiological traits, it is essential for children's furniture design to take into account the impact of furniture on the healthy growth of children's bones. Particularly for desks and chairs, their design should incorporate adjustable structures, such as adjustable tabletop angles and chair backrest angles, to accommodate the dynamic growth needs of children and promote the healthy development of their bones and muscles. To achieve this goal, the introduction of an "angle adjustment device" (Fig. 7) in the design is necessary. This structure allows for fine adjustments to the angles of furniture to meet the requirements of sustainable design for children's furniture. The utilization of this adjustment mechanism not only demonstrates the humanization of children's furniture design but also reflects a deep concern for the healthy growth of children.

This structure belongs to the field of mechanical technology and is a type of tabletop angle adjustment device. The tabletop angle adjustment device comprises a table frame and a movable tabletop. The movable tabletop can flip relative to the table frame. A support portion is provided inside the table frame, and a lifting component is arranged between the support portion and the movable tabletop. The lifting component includes a supporting arm and a driving rod. One end of the supporting arm is hinged to the support portion at a first hinge point. The other end of the supporting arm is slidingly engaged with the movable tabletop. One end of the driving rod is hinged to the support portion at a second hinge point, while the other end of the driving rod is hinged to the supporting arm. The driving rod can extend and retract, causing the supporting arm to rotate around the first hinge point forward when extended, lifting the rear end of the movable tabletop upward. Conversely, when the driving rod retracts, it causes the supporting arm to rotate backward

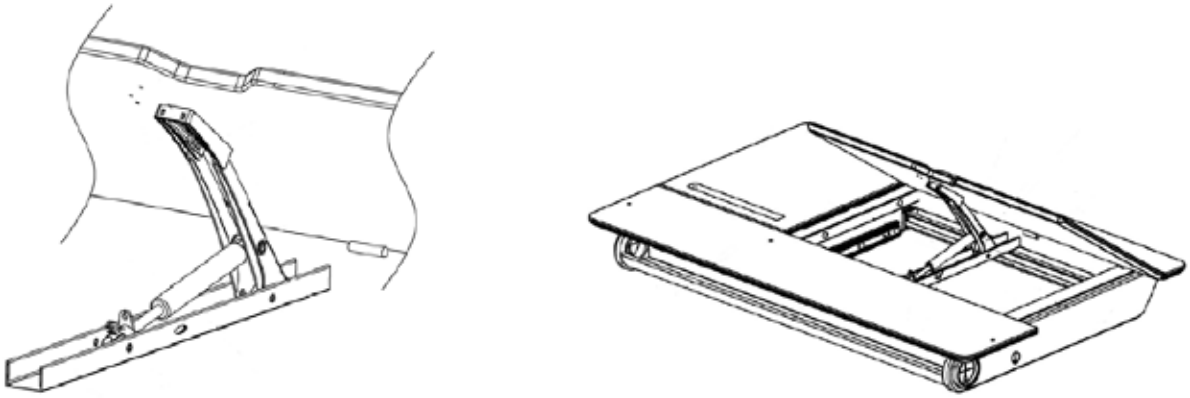


Fig. 7. Desktop angle adjustment device, China, 2021

around the first hinge point, lowering the rear end of the movable tabletop. By driving the supporting arm to rotate using the driving rod to adjust the tilt angle of the movable tabletop, the overall structure is stable and allows the driving rod to open the movable tabletop to a sufficient angle within a relatively short stroke [13].

Variable techniques with fun and puzzles. When discussing the sustainable design of children's furniture, we have identified a core element: "variability." This element not only aligns closely with the evolving physical and mental needs of children but also promotes innovation and adaptability in furniture design. By introducing variability, we can meet children's universal pursuit of engaging and intellectually stimulating designs, while providing them with opportunities for participation, enhancing their sense of belonging and autonomy. Skillfully integrating variability and combinability into design can bring various benefits: a. It can enhance the fun and educational value of furniture, stimulating children's curiosity and desire for exploration. b. It can make furniture design more rich and diverse, catering to the individual personalities and preferences of different children. c. It can promote children's manual dexterity and creativity, enhancing their independent thinking and practical abilities, while fostering their curiosity, teamwork spirit, and confidence. Furthermore, the multifunctionality and combinability of furniture design not only continuously meet the evolving life needs of children but also effectively reduce the cost and frequency of furniture replacement. Moreover, such design variability is crucial for adapting to the physiological and psychological changes children experience from early childhood to adolescence. As children grow, furniture functions, sizes, and designs should be adjusted accordingly to better meet their developmental needs.

Modular Design: "A module is a unit with composability, good reusability, and complete interfaces, which can compose a system." [10]. Modularization is conducted from a systemic perspective to achieve optimal benefits, studying the composition forms of products or systems and reinterpreting them through decomposition and combination methods. When dividing modules in sustainable design for children's furniture, attention should be paid to the following points: The role of modules in the entire furniture and the possibility and necessity of replacement; Maintaining a certain degree of independence and integrity in terms of function and structure within the modules; Ensuring that the connecting elements between modules are easy to connect and detach. The division of modules should not affect the primary function of the overall furniture. Therefore, modular design should be divided into the following points:

– Modular Design of Children's Furniture Overall. In the preliminary stage of modularization of children's furniture, we focus on systematic overall design to establish the implementation framework of modularization strategy [2]. A well-conceived overall design is the cornerstone of achieving modular design objectives. It involves a detailed review of the functions and types of children's furniture, rational division of children's activity areas, and overall organization planning of furniture used by children.

– Modular Design of Children's Furniture Individual Modules. This is the process of concretizing the modular design system and is a link between continuation and initiation. It includes research on the functions of individual modules, determination of dimensions, and studies on the possibilities of combinations.

– Modular Product Design of Children's Furniture. This stage mainly involves selecting modules, evaluating the rationality of possible

module combinations, and then assembling furniture according to consumer needs. It includes selecting individual modules for combination and evaluating the usability and rationality of furniture use after combination.

These three levels require modular furniture design to proceed from top to bottom, from general to specific, and from specific to general, with designs at each level interlocking. Through this modular design, what we will ultimately present is a series of furniture in various forms that can meet the different needs of children (Fig. 8).

Cognitive Development and Enjoyment: In children's furniture design, these are primarily manifested in two key aspects: variability of functions and ease of use and flexibility. Variability of functions means that the furniture can adapt to the needs of children at different stages of growth, providing diverse ways of use to stimulate children's curiosity and exploration. Meanwhile, ease of use and flexibility ensure that the furniture can easily adapt to children's daily activities, providing necessary support for activities such as play, learning, or rest (Fig. 9).

Through meticulous design, these pieces of furniture not only meet children's basic usage needs but also, without sacrificing safety and durability, create enjoyable and educational experiences through variation and combination. This design philosophy helps foster children's independence, creativity, and problem-solving skills, while also providing parents with a furniture solution that can evolve with their child's growth.

Changeable colour technology. The evolution of color perception is crucial for children's psychological development. In response to this developmental need, an innovative concept in children's furniture design has emerged, which cleverly adjusts the structure of the furniture to enable flexible changes in decorative panels, thereby meeting children's diverse color preferences. At the core of this design concept is the creation of easily detachable double-sided decorative panels for the furniture, with each side featuring

Fig. 8. Modular Furniture, Hong Kong, China, 2018

Fig. 9. Fun Furniture, Croatia, 2016

unique colors or patterns. Children can freely flip the panels according to their preferences, effortlessly altering the furniture's appearance. Additionally, the decorative panels are designed to accommodate children's artwork, favorite images, or personalized colors, allowing for the constant updating of the furniture's colors to match children's evolving preferences. This design not only fosters creativity but also provides a personalized and ever-changing environment for growth. To achieve this flexibility, the furniture design adopts a "standardization" approach, which includes the following key aspects:

– Standardization of Design: Ensures consistency in basic design elements and styles across different products, facilitating the uniform updating of colors and patterns.

– Standardization of Components: The standardization of components enables flexible production to a certain extent and improves processing efficiency. By applying the principles of similarity in grouped technology and digital technology, standardization is carried out in terms of dimensions, joints, and profiles of components. Finally, a component standardization library is established using coding technology [12].

– Standardization of Interfaces: Designing uniform interfaces ensures compatibility between different components, facilitating quick replacement and upgrades. Through this standardized design, children's furniture not only adapts to children's evolving preferences but also continuously provides fresh and interesting experiences over time, promoting their psychological and emotional development. As modern hardware factories have established a hardware system based on the "32mm system," where the interface dimensions of hardware components adhere to the "32mm system" dimensions [11]. This project must also adopt the "32mm system" as the interface standard to achieve the sustainability of color design in children's furniture.

CONCLUSIONS

Sustainable design in children's furniture is a multidimensional, interdisciplinary field that demands designers to not only focus on the functionality and aesthetics of furniture but also deeply consider how furniture can meet the ongoing growth, psychological development, and environmental protection needs of children. This study proposes a series of innovative design techniques aimed at steering children's furniture design towards greater sustainability. Research findings indicate that by employing strategies such as adjustable dimensions, angle variations, modular design, color transformations, and standardized design, children's furniture can better accommodate the evolving needs of children's growth while reducing its environmental impact. Through the proposed technical pathways in this study, designers and manufacturers can develop furniture products that not only meet the growing needs of children but also possess environmental performance and cost-effectiveness, providing children with a healthier, more flexible, and personalized growth environment while driving sustainable development in the furniture industry.

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АНОТАЦІЯ

Вень Сіньмяо, Пашкевич К.Л. Сталий розвиток під час проєктуванні дитячих меблів: техніки та засоби.

Мета *дослідження – розроблення багатофункціональних меблів, які відповідають потребам дітей, за допомогою екологічних методів проєктування. Він спрямований на стимулювання розвитку дизайну дитячих меблів до сталого розвитку, зменшення впливу на навколишнє середовище, водночас забезпечуючи дітям більш здорове, гнучке та персоналізоване середовище для росту.*

Методологія*. Використано аналіз літературних джерел, присвячених дизайну дитячих меблів та екологічному дизайну; застосовано міждисциплінарний*

метод для вивчення екологічних технологій проєктування дитячих меблів; також використано метод кейс-аналізу, структурно-функціональний аналіз та ін.

***Результати дослідження** підкреслюють ефективність і практичність методів екологічного проєктування дитячих меблів. Визначено, що завдяки складаним і штабельованим конструкціям досягається регулювання розмірів меблів, що даєзмогу адаптувати меблі до мінливих розмірів тіла та потреб дітей у використанні. Досліджено меблі з регульованим кутом нахилу, які враховують фізіологічні особливості дітей для підтримки їхнього здоров'я та зменшення втоми. Установлено, що впровадження модульного дизайну дає змогу змінювати конфігурацію меблів та їх функціональне призначення у міру росту дітей, підвищуючи як розважальні, так і освітні аспекти меблів, заохочуючи дітей до навчання. Застосування технології варіативності кольорів за допомогою знімних декоративних панелей дає змогу персоналізувати колір меблів відповідно до вподобань і психологічних потреб дітей. Дослідження також розглядає стандартизації дизайну, включаючи стандартизацію компонентів та інтерфейсів, що не лише покращує замінність меблів і технічне обслуговування, а й оптимізує використання ресурсів, знижує виробничі витрати та мінімізує вплив на навколишнє середовище.*

***Наукова новизна** полягає в інтеграції регульованих, модульних та інтелектуально стимулюючих багатофункціональних меблів. Цей технологічний підхід ураховує фізіологічні та психологічні потреби розвитку дітей, підтримуючи їх здоровий розвиток завдяки регульованим кутам і розмірам меблів. Запровадження технологій варіативності кольорів дає змогу дітям змінювати зовнішній вигляд меблів відповідно до їхніх особистих уподобань, покращуючи їх налаштування та інтерактивність.*

***Практичне значення** отриманих результатів полягає у можливості їх застосування для дизайнерів і виробників під час проєктування дитячих меблів.*

Ключові слова: дитячі меблі, сталий дизайн, технологічність, дизайн меблів, багатофункціональні меблі, принципи проєктування.

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