Research on Modular Design of Children's Furniture Based on Scene Theory

Junnan Ye, Wenhao Li, and Chaoxiang Yang(✉)

East China University of Science and Technology, Shanghai 200237, China

Abstract. Modular children's furniture can meet the needs of children's growth for sustainable use due to the diversification of functions and the variability of forms, which has become the main research object in the children's furniture market. Specifically, modular design, as a systematic design method, can effectively shorten the product design cycle, quickly respond to market demands, and extend the product life cycle. Thus, it can help companies quickly grab market share and achieve commercial success. However, through the investigation of the existing modular children's furniture in the market, it is found that most of the products are only for functions, ignoring the emotional needs of users during the interaction with products, such as the satisfaction of intelligence and interest. Scenario theory is a business development concept that understands and interprets user needs from the perspective of users' scenario and accurately adapts services and information, thereby helping companies gain reputation and commercial profits by shaping a higher service experience and service conversion rate. This paper studies the design of modular children's furniture based on the research method of scene theory. This study applies scene theory into the design of modular children's furniture, which can effectively help designers more accurately grasp the relationship between products and users and their needs, thereby further improving product rationality and product satisfaction, and also providing a new and effective exploration for modular children's furniture design.

Keywords: Scene theory · Modular design · Children's furniture · Furniture design · User experience

1 Introduction

With the growth of global urban population, residents' income and investment in the construction industry, coupled with the continuous consumption upgrades and parents' increasing attention to the growth environment of their children, the global children's furniture market continues to expand, with a market share of approximately 100 billion. Modular children's furniture can meet the needs of children's growth for sustainable use due to the diversification of functions and the variability of forms, which has become the main research object in the children's furniture market. Specifically, modular design, as a systematic design method, can effectively shorten the product design cycle, quickly respond to market demands, and extend the product life cycle. Thus, it can help companies quickly grab market share and achieve commercial success. However, through

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the investigation of the existing modular children's furniture in the market, it is found that most of the products are only for functions, ignoring the emotional needs of users during the interaction with products, such as the satisfaction of intelligence and interest.

Scenario theory is a business development concept that understands and interprets user needs from the perspective of users' scenario and accurately adapts services and information, thereby helping companies gain reputation and commercial profits by shaping a higher service experience and service conversion rate. This paper studies the design of modular children's furniture based on the research method of scene theory. First of all, through literature research, observation, interview, and scene analysis, the types of children's furniture, usage scenarios, children's use behaviors, and parents' consumption concepts are investigated, thus creating the objective scene of users' demand for modular children's furniture, with three major functions of "safety and firmness, intelligence and interest, flexibility and durability". On this basis of the objective scene, through the KJ analysis method and AHP analytic hierarchy process, this paper defines the five design requirements for the modularization of children's furniture (reasonable size, fun, versatility, unified style, safety), as well as the order of importance of the five design elements. Furthermore, based on the design principle of furniture modularization, focusing on functional requirements analysis and scene adaptation theory, a set of children's furniture modular system is constructed, with support module and bearing module as the basic modules, graffiti module and game module as special modules and other adaptation modules as the main content. The furniture modular system adopts plug-in module connection mode, square and round geometrical module form, and module size in line with ergonomics. Besides, natural materials such as solid wood are used as the main materials. Finally, DFMA technology is introduced to analyze and evaluate the modular combination mode, manufacturing process and production characteristics of the children's furniture modular system to verify the feasibility and effectiveness of the design practice.

This study applies scene theory into the design of modular children's furniture, which can effectively help designers more accurately grasp the relationship between products and users and their needs, thereby further improving product rationality and product satisfaction, and also providing a new and effective exploration for modular children's furniture design.

2 Theoretical Research

2.1 Scene Theory

Scene theory is a user-centered design method inspired by several disciplines, such as anthropology, psychology, and design [1]. Its core is to understand and interpret user needs from the perspective of the user's scene, and to accurately adapt services and information to provide the users with creative solutions. Scene theory is characterized by flexibility, rationality, co-rationality, landing and standardization. There are mainly two ways to classify scene types in scene theory. The first one is to classify according to structured scenes, which can be divided into value scenes, activity scenes, and interactive scenes. The other is to divide the scene into objective scenes and target scenes, simulation scenarios, application scenarios according to the different stages of design.

2.2 Children's Furniture

Children's furniture is designed specifically for children to sit, lie down, or support and store items in their life, works or social practice. It needs to meet children's physical and psychological needs. Furniture is more than a simple functional material product, but is an important part in the daily life [2]. It must meet certain specific uses and provide certain aesthetic pleasure to arouse the associations in the process of contact and use.

2.3 Modular Furniture

Modular furniture design indicates the combination of a series of furniture functional modules through standardized interfaces [3]. It is applied in the design of the entire furniture product system, and is a standardized and modular design. The modular design of furniture mainly includes two aspects: module establishment and module combination.

3 Modular Children's Furniture Design Method and Process Based on Scene Theory

The scene design theory is composed of four stages [4]: (1) collection of scene user data; (2) the integration of data and construction of the scene model structure; (3) using data to prototype product and service concepts; (4) testing and improving the product concept. The procedures are shown in Fig. 1.

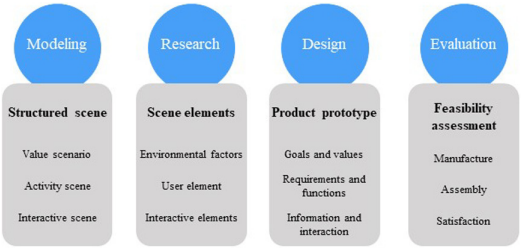


Fig. 1. Design method of scenario theory

3.1 Project Initiation Phase-Collecting Objective Scene Data

During the start-up phase of the project, the data collection of objective scenarios is required to understand the background of the target product. The intrinsic needs of users can be identified by collecting user-related data. Quantitative methods, such as questionnaire surveys or content analysis, and qualitative methods, such as interviews or observation can be used for data collection.

3.2 Structured Scenario-Build the Target Scenario Model

Before the scene model is constructed, the collected scene data should be sorted out, and the user settings under the target scene should be summarized. After that, a value scenario model will be created to fulfill the user's internal needs. The purpose of the value scenario model is to show the product goals in the scenario and provide the keywords in the design. Subsequently, an activity scenario model based on value scenario and user settings will be created to visually display the collected user activity information, construct the tasks and goals that should be completed, and to determine the product opportunity points. Finally, an interactive scene model based on the activity scene and user settings will be created to explain the required operations and interactions for the tasks and goals in the activity scene model. It is necessary to combine the characteristics of the hardware and the user to provide a feasible system solution to the manufacturing of the product.

3.3 Product Design-Design Simulation Scenarios

It is difficult to imagine the specific image of the product and the process structured in the scene based on the description of the text. At this stage, it is necessary to design a specific solution and to visualize the needs of the user in the scene through the prototype of the scheme and the design of the product.

3.4 Program Usability Evaluation-Test Actual Application Scenarios

By using the design method based on scenario theory, the structured scenarios provide a process of "evaluation" and "visualization" for each stage. After each stage of the structured scene is completed, a scene model evaluation will be required. After all the construction target scenes are constructed and the visualization scheme is completed, a complete round of overall feasibility evaluation of the scheme will be carried out.

4 Research on the Functional Requirements and Use of Children's Furniture

4.1 Research Purpose and Content

(1) Research purpose
The purpose of this survey is to clarify the specific functional requirements and the problems with the furniture in children's rooms to help with the construction of children's furniture modular systems.

(2) Research content
The content of the survey is mainly divided into two parts: ❶ Observe the usage of children's furniture, such as tables and chairs, bed cabinets, and storage, including the interaction between children and furniture and the occurrence of problem. ❷ Conduct interviews with children's parents to understand the consumption tendency of children's furniture and the demand for the product.

4.2 Research Method and Process

(1) Research methods: observation, unstructured interview
(2) Research process: The investigation of the using of children's furniture is divided into six steps (see Fig. 2).

Fig. 2. Investigation and research process

4.3 Research Places and Users

(1) Research site
A field survey is conducted on the households of middle-income families with children aged 0–12 in Huangshi City. The children's rooms in 5 residential communities were visited, mainly in the Nanjing Road Community, Tianfang Rose Garden, Huangshi Port District. Hubin Avenue No. 34 Community, Huangshigang Bridge South Community.
(2) Research users
The subjects of this survey include 30 children and their parents.

4.4 Usage of Children's Furniture for Children Aged 0–12

The user pattern of children's furniture is mainly obtained by observing the behavior of children and their parents in using the furniture in the following two scenarios:

(1) Children and parents use tables, chairs, bed cabinets, and storage furniture;
(2) Children's spontaneous behaviors when using tables, chairs, bed cabinets, and storage furniture.

By summarizing children' pattern in the above two scenarios, the behavior and problems of three types of children's furniture are extracted, and the individual functional needs for children's furniture is listed in Table 1.

Table 1. Functional requirements and usage of children's furniture

	Behavior	Functional needs	Usage and problems
Tables and chairs	Sit and learn	Load bearing	Unreasonable size, unable to adjust flexibly
	Stationery, toys placement	Item placement	Insufficient free space on desktop
	Doodle on the desktop	Doodle game	The graffiti traces on the desktop are difficult to clean up
Bed cabinets	Go to bed	Safe and comfort	The distance between the railings of the children's bed is not appropriate, some cannot protect it, and some are easy to jam the child
	Clothing storage	Organize storage	Unreasonable size and capacity, unable to adjust flexibly
	Cabinet door graffiti	Doodle game	Graffiti traces are difficult to clean
	Space organization	Environment layout	If the furniture is too large and the center of gravity is unstable, it will cause the children's furniture to fall and hurt children
Storage	Books and toys placement	Item placement	The storage unit is too small and it is inconvenient to get things

4.5 Functional Requirements of Children's Furniture

The furniture usage in Table 1 is sorted and classified based on the needs of both parents and children. The functional requirements of children's furniture system can be obtained, which can be divided into three categories:

(1) Safe and firm. Given children's low awareness of self-protection and their active nature, safety is the primary factor in the design of children's furniture. It includes structural safety, material safety, and color safety [5].
(2) Flexible and durable. Many existing children's furniture are only brightly-colored miniature of adult furniture, without considering the characteristics of children's physical and psychological growth [6]. Therefore, singular function and style, unreasonable scale, and lack of sustainability are the main problems that obstruct the development of children's furniture [7]. The modular design of children's furniture not only expands the use of children's furniture, but also solves the problem of homogeneity in design.

(3) Puzzle and interesting. Children's furniture must first be safe to use, and should meet certain requirements for guidance, education and intellectual development. In early childhood education, "play" is used as a cognitive means to form a thinking mode [8]. Games are the lifestyle of children, and designing furniture is about presenting a lifestyle [9]. Meanwhile, the design of educational furniture can attract children's attention and improve their practical ability and coordination in the process of using the furniture. Therefore, children's furniture should be educational and interesting.

5 Construction of the Target Scene Model of Modular Furniture for Children

5.1 Research on the Design Requirements of Modular Furniture for Children

Before carrying out the modular design, it is necessary to clarify the specific constraints and the design requirements [10]. Based on the observations and interviews in Chapter 3, we use the KJ analysis method to collect information from the perspective of the designer and clarify the requirements. The specific research process is as follows:

(1) Decide the theme: KJ analysis is applied to explore the design requirements of modular furniture for children.
(2) Method of collecting information: collective BS method.
(3) The process of information collection: ❶ Determine the members of the discussion group, including a furniture industry designer, a furniture manufacturer, a professional with a master's degree in furniture, and two doctoral students. ❷ Define goals. ❸ Build consensus. ❹ Start a brainstorming: gather the group members to brainstorm on the design requirements of furniture modularization, and to summarize the proposed furniture modularization into phrases. Record these notions on the cards, and eliminate the cards with the same meaning. The remaining card is called the "basic card" (see Fig. 3).

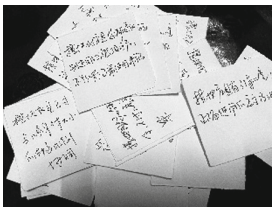


Fig. 3. Basic card

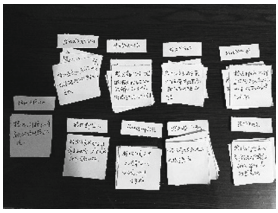


Fig. 4. Team title card

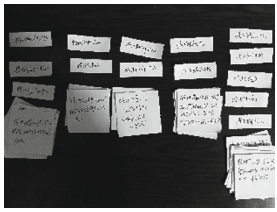


Fig. 5. Large group of title cards

(4) Marshalling

1. Put all "basic cards" on the desktop;
2. All the members form a card group to discuss the requirements according to the cards with similar meanings;

3. Analyze and summarize the content of the cards in the group, and use an appropriate title to review the common points of the cards in the group. Write this title on a card as a "group title card" (see Fig. 4);
4. Regard the "group title card" as an individual, merge the "group title cards" with similar content again, and name the appropriate title as the "large group title card" (see Fig. 5);
5. Draw the conclusion.

The specific content of the three-level cards are summarized, and the information is shown in Table 2. The content of the "big group title card" indicates the modular design requirements of children's furniture. It includes ① scientific and reasonable modular size; ② educational and interesting elements in the modular; ③ universality of the modular; ④ unified style of the module; ⑤ safety. Since the hierarchy between the five requirements is not yet clear, it is necessary to conduct AHP analysis into these five design requirements.

Table 2. Modular design requirements for children's furniture

Basic card	Subtitle card	Headline card
The structural proportions of the modular furniture size and the child's body size are coordinated	Scientific and reasonable modular size	Scientific and reasonable modular size
The module has the ability to grow, and the furniture size can be adjusted, which can extend the life cycle		
The size of the module meets the ergonomic requirements of children of the target age, and is comfortable		
Modular modeling cartoon	Modular form interesting	Educational and interesting elements in the modular
Module modeling biomimetic		
The modular shape design has a sense of rhythm and rhythm, and follows the principle of order		
The module has strong practicability, multi-purpose, modular combination of diversified functions, customizable, and can meet the needs of individual customization	Module function puzzle and interesting	
The module has complete functional configuration to meet the differences in the functional needs of children at different ages		
Modular furniture meets children's play behavior		

(*continued*)

Table 2. (*continued*)

Basic card	Subtitle card	Headline card
Module assembly can cultivate children's hands-on and practical ability, stimulate children's imagination, and exercise creative thinking		
Module assembly can strengthen parent-child interaction and enhance the emotional communication between parents and children		
Module technology and structure are standardized and highly versatile	Universality of the modular	Universality of the modular
The module is easy to use, convenient for children to use		
Systematic modular design, recyclable, reusable, and interchangeable		
Modular style conforms to children's natural nature, individuality, freedom and authenticity	Unified style of the module	Unified style of the module
The style of the module is unified with the style of children's living environment		
Module color matching is overall coordinated and soft		
Modular furniture decoration and beautification are compatible with the use function, and does not affect the normal use function		
The module structure has strong stability, ensuring safety in any state of use	Module structure safety	Safety
Module combination should use hardware reasonably, so as not to cause noise pollution to children		
The module should have a safe design that guides children to use correctly		
The modular furniture switch is closed with a protective device, and ventilation is carried out in a confined space		
The surface of the module material is easy to clean and wear-resistant	Module material safety	
Module material meets the comfort of children's touch		

(*continued*)

Table 2. (*continued*)

Basic card	Subtitle card	Headline card
The module material has strong chemical stability, no irritating odor, and does not cause children's olfactory hypersensitivity		
The base material and auxiliary materials of the modular furniture are all green materials, no pollution		
Modular shape modeling uses soft curves, and the edges and corners are rounded	Module form safety	
The module form has strong visual stability		
Modular furniture should have warning signs for dangerous behaviors to help children avoid danger		
The color of the module is not over-stimulating, prevents visual fatigue and protects the development of the optic nerve	Module color safety	
Color selection is in line with the characteristics and preferences of the target child's age group		

5.2 Level Analysis of Modular Design Requirements for Children's Furniture

AHP analytic method is used to analyze the modular design requirements of children's furniture, and the importance of the five-point design requirements is ranked in accordance with expert scoring and rational data weight analysis. The details are as follows:

The 5 points of modular design requirements obtained in 4.1 were drawn into a design requirement importance score sheet, and a total of 10 designers were invited as the experts to evaluate the importance of the design requirements from the perspective of furniture design by applying the scoring standards (Table 3).

Table 3. The scoring standards of the importance of furniture modular design requirements

I is absolutely important to J. Fill in "5:1" in the corresponding box
I is very important compared to J, fill in "4:1" in the corresponding box
I is obviously more important than J, fill in "3:1" in the corresponding box
I is slightly more important than J, fill in "2:1" in the corresponding box
I is as important as J, fill in "1:1" in the corresponding box

(2) According to the above-mentioned scoring standards, a score sheet for the modular design requirements of children's furniture can be obtained. It has a total of 10 copies. Table 4 is a diagram of the score sheet.

Table 4. An example of the scoring sheet of modular design requirements

I	J				
	The scientific and reasonable size of the module	Safety	Universality of the modular	Unified module style	Educational and interesting elements in the modular
The scientific and reasonable size of the module	1	1/4	2	2	1/2
Safety	4	1	2	4	2
Universality of the modular	2	1/3	1	2	1
Unified module style	1	1/5	1	1	1/2
Educational and interesting elements in the modular	2	1/2	2	2	1

(3) According to the scoring sheet of the modular design requirements of children's furniture, the importance evaluation matrix B can be obtained. The eigenvector W of the matrix can be calculated.

$$B = \begin{bmatrix} 1 & 1/4 & 2 & 2 & 1/2 \\ 4 & 1 & 2 & 4 & 2 \\ 2 & 1/3 & 1 & 2 & 1 \\ 1 & 1/5 & 1 & 1 & 1/2 \\ 2 & 1/2 & 2 & 2 & 1 \end{bmatrix}$$

B_{ij} represents the degree of importance of the modular design requirement i relative to the modular design requirement j, $B_{ij} = 1/B_{ij}$.

The importance of the modular design of children's furniture is calculated according to the following formulas:

$$\overline{w_i} = \sqrt[m]{\prod_{j=1}^{m} B_{ij}}$$

$$w_i = \overline{w_i} / \sum_{i=1}^{m} \overline{w_i}$$

Where Wi is the weight required for modular design of children's furniture.

Afterwards, the weights required for modular design of children's furniture are shown in Table 5.

Table 5. Weights required for modular design of children's furniture

Expert number	Element				
	The scientific and reasonable size of the module	Safety	Universality of the modular	Unified module style	Educational and interesting elements in the modular
01	0.1606	0.4004	0.1541	0.0847	0.2002
02	0.1301	0.5004	0.0932	0.0587	0.2176
03	0.1623	0.3840	0.2047	0.1126	0.1364
04	0.1418	0.3925	0.2808	0.0827	0.1022
05	0.0921	0.4166	0.1339	0.0905	0.2669
06	0.1741	0.4521	0.1053	0.0720	0.1966
07	0.1269	0.3387	0.2168	0.1322	0.1853
08	0.1295	0.4122	0.1440	0.1251	0.1892
09	0.2204	0.4330	0.1080	0.0721	0.1665
10	0.0795	0.1867	0.1320	0.0641	0.5377
Average weight	0.14173	0.39166	0.15728	0.08947	0.21366

By comparing the weight values in Table 5, we can see that the modular design requirements of children's furniture can be ranked in the descending order of importance. ① Safety; ② educational and interesting elements in the modular; ③ universality of the modular; ④ the scientific and reasonable size of the module; ⑤ unified module style.

5.3 Decomposition of Requirements for Modular Design of Children's Furniture

Generally, modular furniture design can be divided into three steps: (1) modular overall design; (2) modular design; and (3) modular product design [11]. The above-mentioned five-point design requirements should also correspond to the specific design content in the requirements (Table 6), so that it can guide the directional and purposeful implementation of modular design.

Table 6. The corresponding requirement and solutions in the design stage

Corresponding to the design stage	Claim	Solution
Overall module design	Universality of the modular	Module function analysis
Modular design	The scientific and reasonable size of the module	Module size meets ergonomic requirements
Modular product design	Safety Unified module style Educational and interesting elements in the modular	Reasonable design according to specific design requirements

6 Modular Children's Furniture Design and Evaluation

6.1 Construction of Modular System for Children's Furniture

When carrying out the modular design of children's furniture, a modular system, and the framework of the modular furniture system should be constructed in a standardized and systematic way of thinking. Modular system construction is mainly composed of three parts: modular object division, module function integration and module division.

Object Division of Children's Furniture Modules. There are many types of children's furniture. Before building the modular system, the objects of modular furniture implementation should be clarified to select the individual type of furniture that is suitable for modular design. Children's furniture mainly includes three types: tables and chairs, bed cabinets, and storage. The requirements of modules should be universally combined. In this study, we put bed cabinets and storage furniture in the same modular furniture system.

Functional Integration of Children's Furniture Modules. The division of children's furniture should be based on the function of the furniture [12]. Therefore, the function of the furniture should be analyzed and integrated. In view of the importance of the function of furniture, the total function of the furniture can be decomposed into basic functions, installation functions, special functions, adaptive functions and user functions.

Division of Children's Furniture Modules. The modules of children's furniture corresponding to the above five functional types can be divided into basic modules, special modules, interface modules, adaptive modules, and non-deterministic modules.

(1) Basic module. The basic module corresponds to the basic function, which is mostly the bearing function [13]. Therefore, the basic module of children's furniture includes two furniture modules: bearing module and support module.
(2) Special modules. Special modules correspond to special functions. The game function is a special function setting up to meet the special needs of children [14]. Therefore, special modules include game modules such as peeping module and graffiti module.

(3) Interface module. The interface module corresponds to the installation function and is used to connect the basic module to realize the functional combination of the module. In view of the different connection modules, the interface modules can be divided into a bearing module interface module, a support module interface module and a game module interface module.
(4) Adaptation module. The adaptation module corresponds to the adaptation function. Due to the different needs of children with different body sizes for furniture, children's furniture needs to be equipped with adaptation modules to meet the needs of children at different ages.
(5) Non-deterministic module. Non-deterministic modules correspond to user functions. For children's furniture, the functional modules that can satisfy children's potential game behaviors are non-deterministic modules, which belong to the extended part of the modular system and should be enriched in the subsequent research.

In accordance with the above analysis, the framework of the modular system of children's furniture is shown in Fig. 6.

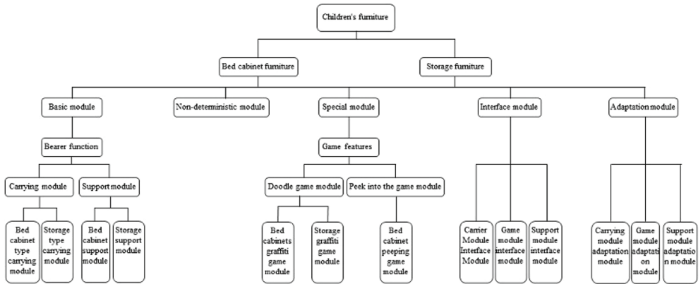


Fig. 6. Children's furniture modular system

6.2 Design Scheme Display

Module Display. Based on the design principle of furniture modularization, focusing on functional requirements analysis and scene adaptation theory, a set of children's furniture modular system is constructed, with support module and bearing module as the basic modules, graffiti module and game module as special modules and other adaptation modules as the main content (see Tables 7 and 8). Different support modules are connected through the interface module to construct a furniture frame, and then load-bearing modules, game modules, are placed to form a modular furniture unit. The furniture modular system adopts plug-in module connection mode, square and round geometrical module form, and module size in line with ergonomics. Besides, natural materials such as solid wood are used as the main materials.

Table 7. Support module icon

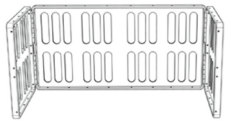
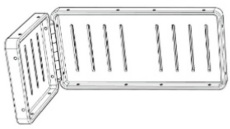
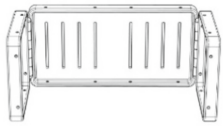
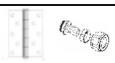
Single-layer bidirectional support module	Single-layer three-way support module	Double-layer three-way support module
		
Single layer bidirectional support module 2	Single layer bidirectional module support 3	Single-layer three-way module support 2
		

Table 8. Diagrams of other modular parts

Load-bearing module/Tuya module	Interface module	Adaptation module	Peek into the game module
			

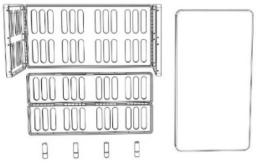
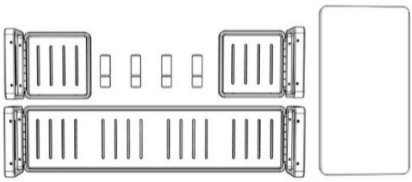
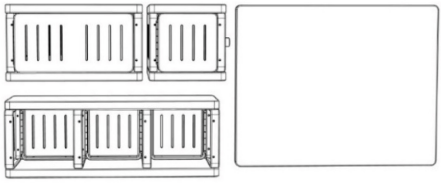
Modular Furniture Display. The children's furniture in the modular furniture system includes cribs for 0–3 years old, beds for 3–6 years old and for 6–12 years old, bookcases and wardrobe for 3–6 years old, and growth Style wardrobe for 0–12 years old. The furniture is obtained through the combination of various modules, as shown in Table 9.

Modular Furniture Scene Display. The above modular can be combined and matched to form the furnishings of children's room, which is shown in Fig. 7.

6.3 DMFA Technical Analysis of Modular Children's Furniture

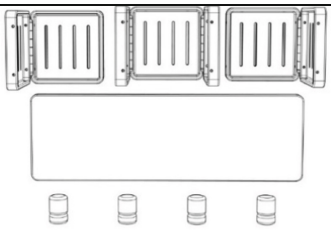
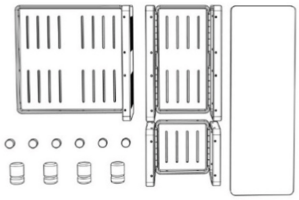
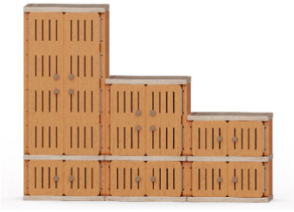
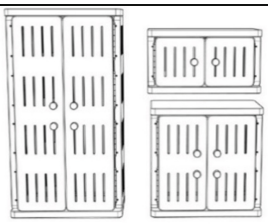
Design for manufacturability (DFM) manifests the essence of improving the current manufacturing process of the product [15]. The application of DFM technology mainly focuses on analyzing the manufacturability of design information, evaluating the rationality of manufacturing, and making improvement in the design [16]. Therefore, it is necessary to consider the relevant characteristics of the product, such as assemblability and manufacturability, in the design.

Table 9. Modular furniture

Cribs for 0-3 years old	
	
Use part modules: Load-bearing module, support module, interface module, peeping game module, adaptation module	Combination method: Double-layer three-way support module + peeping game module + interface module = guardrail Load-bearing module = bed board Adaptation module*4=bed leg
Beds for 3-6 years old	
	
Use part modules: Load-bearing module, support module, interface module, adaptation module	Combination method: Single-layer three-way support module 3 + single-layer two-way support module * 2 + interface module = guardrail Load-bearing module = bed board Adaptation module*4=bed leg
Beds for 6-12 years old	
	
Use part modules: Load-bearing module, support module, interface module, adaptation module	Combination method: Single-layer three-way support module + single-layer two-way support module*2+single-layer two-way support module 3*4+single-layer two-way support module 2*4+adaptation module*4+load-bearing module*10=bed Load-bearing module = bed head

(*continued*)

Table 9. (*continued*)

Bookcases for 3-6 years old	
	
Use part modules: Load-bearing module, support module, interface module, adaptation module	Combination method: Single-layer two-way support module*6+Single-layer three-way support module*3+bearing module*4=bookcase Adaptation module*4=cabinet feet
Wardrobe for 3-6 years old	
	
Use part modules: Load-bearing module, support module, interface module, adaptation module	Combination method: Double-layer two-way support module*2+Double-layer three-way support module 2+Single-layer three-way support module*3+Load-bearing module*3+Adaptation module*6=Wardrobe Adaptation module*4=cabinet feet
growth Style wardrobe for 0-12 years old	
	
Use part modules: Load-bearing module, support module, interface module, adaptation module	Combination method: Four-layer three-way support module*2+Double-layer three-way support module 2*2+Single-layer three-way support module*8+Load-bearing module*9+Adaptation module*16=Wardrobe

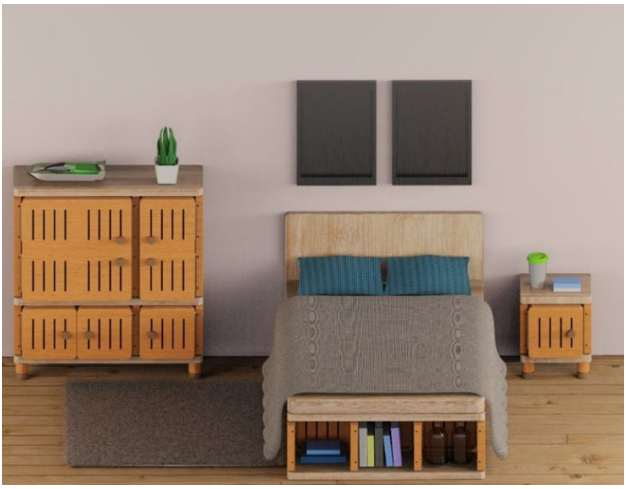


Fig. 7. Children's furniture scene display

Manufacturability Analysis and Optimization. By determining the specific production size of modular furniture, adjusting the proportions, determining the small-scale model manufacturing plan, selecting the three-plywood as the main model processing ingredients, processing raw materials such as running-in and cutting, and selecting the smallest-size hardware connectors for assembly, we can verify the manufacturability of modular furniture [17].

Assemblability Analysis and Optimization. The evaluation of assemblability should consider three aspects: cost, efficiency and technology [18]. Since the design has not been put into mass production, this study cannot obtain the cost and efficiency of the assembly unit. We can predict that these aspects are affected by the following factors: the number of parts, the type of parts, and the reasonable unit product structure, the assembly steps, the difficulty of assembly, the quality of each assembling step, the reasonable degree of assembly plan and resource planning. In the entire assembly process of the product, the technical characteristics should be improved to ensure that the technology is easy to use.

Although the quantitative evaluation index of the actual data cannot be obtained due to the lack of objective data, the qualitative evaluation of the assembly of children's furniture can be carried out by taking the above-mentioned influencing factors into account [19]. In other words, the less the number of parts, the greater the variety; the more reasonable the unit product structure, the fewer the assembly steps; the simpler the assembly action, the more reasonable the assembly plan and resource planning; the lower the cost of assembly action and the less the time wasted in the design, the higher the assemblability. Modular children's furniture should follow the principle of universality. The modules are simple and unified, the structure is reasonable, so that the design can be assembled more easily.

7 Summary and Forward

This paper studies the design of modular children's furniture based on the research method of scene theory. The main achievements are as follows:

(1) Through literature research, observation, interview, and scene analysis, the types of children's furniture, usage scenarios, children's use behaviors, and parents' consumption concepts are investigated, thus creating the objective scene of users' demand for modular children's furniture, with three major functions of "safety and firmness, intelligence and interest, flexibility and durability".
(2) On this basis of the objective scene, through the KJ analysis method and AHP analytic hierarchy process, this paper defines the five design requirements for the modularization of children's furniture (reasonable size, fun, versatility, unified style, safety), as well as the order of importance of the five design elements.
(3) Furthermore, based on the design principle of furniture modularization, focusing on functional requirements analysis and scene adaptation theory, a set of children's furniture modular system is constructed, with support module and bearing module as the basic modules, graffiti module and game module as special modules and other adaptation modules as the main content. The furniture modular system adopts plug-in module connection mode, square and round geometrical module form, and module size in line with ergonomics. Besides, natural materials such as solid wood are used as the main materials.
(4) Finally, DFMA technology is introduced to analyze and evaluate the modular combination mode, manufacturing process and production characteristics of the children's furniture modular system to verify the feasibility and effectiveness of the design practice.

Meanwhile, due to the limited depth of scientific research and constraints of time, this research has certain deficiencies that calls for further effort.

(1) Since the main body of the article is about modular children's furniture, the research on scene theory should be conducted;
(2) The sample size is not sufficient, and the summary of children's behavior is not comprehensive enough. These will result in the division of furniture modules, which cannot meet the needs of all children. In the future study, children's furniture environment life, and game activities should be included to expand and update the module library;
(3) The exploration of the connection mode between the modules is not profound enough, as it is impossible to conduct a systematic study on the connection mode. The subsequent research on the modularization of children's furniture might start from analyzing the connection method of the modules, specifically the combination and connection methods of the modules, to improve the modular design of children's furniture.

References

1. Holtzblatt, K., Wendell, J.B., Wood, S.: Rapid contextual design: a how-to guide to key techniques for user-centered design. Ubiquity **2005**(March), 3 (2005)
2. Wen, Q.K.: Research and design of smart high-speed rail travel products based on scenario theory. Master, South China University of Technology (2019)
3. Chen, Z.: Research on the market analysis of children's furniture design. Master, Nanjing University of Science and Technology (2007)
4. Lin, H., Hua, Y.C., Yang, W.J.: On the modular design of mass-customized furniture. China Forest Prod. Ind. **3**, 10–12+42 (2004)
5. Cao, Y.F., Mu, Y.P., Duan, H.Y.: Humanized design of children's furniture. J. Northwest Forest. Univ. **24**(01), 173–176 (2009)
6. Huang, W.H., Yang, C.: Children's furniture explore innovative applications. Arts **12**, 197–198 (2012)
7. Liu, X.H., Zeng, H.: Domestic children furniture market analysis. Furniture **3**, 53–56 (2005)
8. Zhang, H.Y., Wang, F.H.: Design of biological furniture in the child amusement park. Furniture Inter. Des. **3**, 22–23 (2010)
9. Ji, X.D.: Preschool children furniture modeling design. New Technol. New Prod. China **16**, 97 (2010)
10. Dai, X.: Modular design of kindergarten children's furniture based on activity area division. Master, Nanjing University of Science and Technology (2018)
11. Ning, X.: Research and design practice of modular children's cardboard furniture. Master, Beijing Forestry University (2015)
12. Wang, S.: The application of modular design in product design. Furniture Inter. Des. **1**, 22–23 (2018)
13. Wu, Q., Jia, K., Liu, Y.: Sustainable design of children's bed based on Modularization. Packag. Eng. **40**(18), 140–144+175 (2019)
14. He, W.: A new probe into the design of interesting children's furniture. Packag. Eng. **40**(10), 294–296 (2019)
15. Qu, Y.T.: Research on the design of customized furniture modular system based on DFMA technology. Master, China Academy of Art (2019)
16. Sun, X.F.: DFA technology and application research. Master, Liaoning Technical University (2004)
17. Ye, W., Zhu, Y.: Design research on the shape and structure of customized furniture. Furniture Inter. Des. **3**, 14–15 (2018)
18. Du, J.W.: Food machinery design for manufacturing and assembly. Mach. Equip. **1**, 34 (2017)
19. Jeffrey: Assembly Automation and Product Design. Mechanical Industry Press, Beijing (2009)