



Research on the Design of Children's Growth-oriented Furniture Based on the TRIZ Theory

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Abstract

Objectives: It is expected that the problems of both practicability of children's furniture and their conformity to children's growth law can be solved, and design scheme of children's growth-oriented furniture can be put forward based on the TRIZ theory. **Methods:** Firstly, the requirements and position of users are evaluated from the physiological, and behavioral, cognitive and emotional perspective. Secondly, the inventive principle is analyzed based on the presupposed settings. Thirdly, the solution is proposed on the basis of component analysis, transactional analysis and function model. Finally, technical and physical contradictions are solved and the scheme is output. **Result:** The principle of the TRIZ theory is applied to analyze the function, thus realizing the practicability and growth ability of the product. **Conclusions:** The inventive principle and the requirements of design are combined, which provide references for the design of children's growth-oriented furniture.

Keywords

Children's growth-oriented furniture, TRIZ theory, User study, Innovative design method

Introduction

Children are undergoing a period in which their physiological functions develop and change rapidly, and they are also in a period with rapid development of psychological aspect, cognitive ability and social behavior. However, products in current market lack the concern for children's physiological and psychological growth. This paper takes children's growth-oriented furniture as the example, integrates the TRIZ theory and children's growth requirements into the design process, explores and solves the problem of simultaneous satisfaction of practicability and long-acting effect, and obtains the innovative design method with the growth ability for children's furniture.

1. Product design process of children's growth-oriented furniture based on the TRIZ theory

The design process of children's growth-oriented furniture is a process of determination, analysis and settlement of problems, and scientific design process can guide and solve problems smoothly. The research starts from the three aspects of finding, analyzing and solving problems, takes advantage of the TRIZ tool to analyze the demands of children's growth-oriented furniture design, forms the design process, which starts from the characteristics of children's growth and analysis by the TRIZ theory, and puts forward the solution, analyzes the solution in combination with usage scenarios, verifies the feasibility and humanization, and formulates the normalized process conforming to the development and design of children's growth-oriented furniture. The concrete steps for implementing the design process of children's growth-oriented furniture on the basis of the TRIZ theory are as follows:

(1) Determination of problems: Current products are analyzed and the design object is determined. Physiological, behavioral, emotional and children's cognitive characteristics are analyzed according to the characteristics of design object's growth, and users' requirements are further explored. In view of the main problems, requirements such as safety, environmental protection, multi-function, growth potential, game experience, space saving, etc. are proposed.

(2) Analysis of problems: Inventive principles applied to meet different design requirements are analyzed. Functional analysis is conducted through component analysis, transactional analysis and graphical function model.

(3) Settlement of problems: The contradiction and conflict are analyzed from technical and physical aspects on the basis of product functions, and solutions are thus founded. Design direction and solutions are clarified with the help of the TRIZ theory, and the scheme is output, whose scenario is simulated to determine whether it can meet the design requirements. The complete scheme is output and tested by models, thus optimizing it and iterate it for the second time. The model of the design process is shown in Figure 1.

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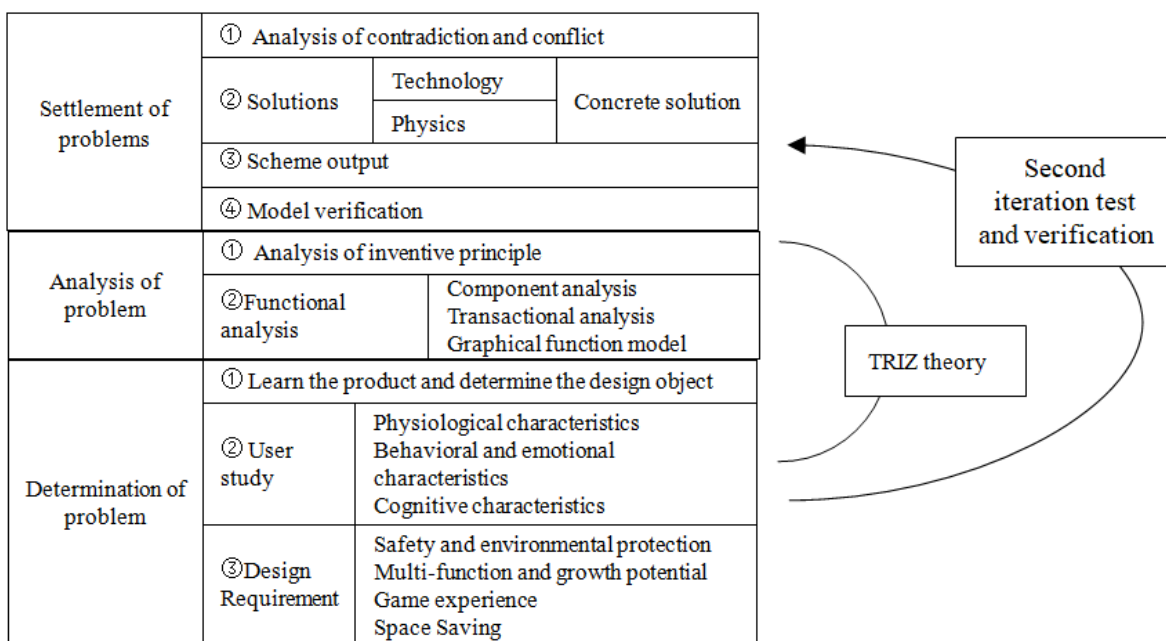


Figure 1. Design process of children's growth-oriented furniture based on the TRIZ theory.

2. User demand and design orientation of children's growth-oriented furniture

2.1 Analysis of children's growth characteristics

With the continuous growth of height, weight, muscle strength, etc. at the stage of childhood, children's physiological characteristics, behavior and habit also change a lot, and show apparent stage characteristics.

In terms of physiological characteristics, 3-5 years children's major muscles grow rapidly, body actions become gradually flexible and coordinated, minor muscles develop a lot, and the abilities of doing fine movement, such as building blocks, stringing beads, kneading clay, paper folding, painting, using scissors, etc. The process of the inhibitory and excitation of children at the age between 6-12 becomes gradually balanced, and children's physical development is relatively stable, which requires furniture that fits their height to prevent from the scoliosis due to inappropriate postures (Liu Runxi, Lv Jiufang, Liang Xiao, & Quan Yuan, 2018).

In terms of children's behavioral and emotional characteristics, children of 3-5 years old tend to be dominated by their emotions, with a strong imitative ability and intuitive thinking, can understand and abide by simple rules. 6-12 years old children's ability to control their emotions gradually improves, with poor endurance. They pursue the independence of intelligence, gradually equip with the thinking ability of reasoning, and their memory and reading ability also gradually develop.

In terms of children's cognitive characteristics, children at the age of 3~5 can concentrate within a certain period. Their cognitive abilities of the surface properties and functions of objects, usage scenarios, etc. gradually improves, and they show great interests on vivid colors, lines, rhythm, and voice. 6-12 years old children's attention is not stable. The development of their intuition and observation ability turns from an unintentional, emotional, careless state to a more purposeful, organized and precise one, and their abstract logical thinking begins to tightly combine with perceptual experience.

The demand of children's furniture generated by physiological, behavioral, emotional and cognitive characteristics varies at different stages of age, which can be summarized as follows after investigation: During 3-5 years old, children need furniture with lively colors, full enjoyment and storage ability. During 6-7 years old, children need furniture with the integration of learning and entertainment functions. During 8-10 years old, children need furniture with more complete functions. During 11-12 years old, children have higher requirements on functions such as learning auxiliary and comfort. Therefore, the users ages are determined between 3-12, which are further divided into two stages: 3-6 years old (preschool) and 6-12 years old (school age).

2.2 Design position of children's growth-oriented furniture

To satisfy the diversified market demands, the development of children's growth-oriented furniture in the future is mainly carried out from the following four aspects:

(1) Safe and environment-friendly furniture

The design concept of safety has important significance for preventing potential safety hazards caused by children's immature physiological and psychological functions when using the furniture. The materials must be poisonless, harmless, suitable in size and firm in structure.

(2) Multi-functional and growable furniture

The furniture shall grow and its function shall change with the growth of children. With the collocation and combination of components, the furniture's operational and accessible property at certain ages can be optimized, which responds to the concept of sustainable design.

(3) Game type furniture

During the process of designing children's furniture, the most proper balance point should be found between practicality and enjoyment. The furniture shall be conducive to cultivating children's habit of practice, thinking and arrangement, and cultivating their intelligence and the ability of self-control.

(4) Space saving furniture

The furniture with the storage feature has an important position in small-sized apartments. The problem of using components' ability to store itself to reduce spatial occupation should be considered.

3. Analysis of product design method and function

3.1 Inventive principle of children's growth-oriented furniture

The design requirements of children's growth-oriented furniture changes according to the physiological and psychological characteristics of children's growth. During designing and making the children's growth-oriented furniture, the TRIZ inventive principle can be used to classify according to design requirements. Functional analysis is the tool for the TRIZ theory to analyze problems. In order to meet the design requirements of safety and environmental protection, local quality is used to make different parts of the object have different functions (Peng Min, 2014). Prior action is used to provide necessary changes for the object (the whole or at least parts of it) in advance. Precaution is adopted, and emergency measures prepared in advance are used to compensate for the relatively poor reliability of the object. In the design requirements of realizing multi-function, growth potential, segmentation is used to divide an object into mutually independent parts. The object is divided into parts that are easy to disassemble and assemble. Combination is applied to combine together objects with different (or opposite) functions to realize new functions. Versatility is adopted to make an object equip with multiple functions, and to eliminate the necessity of the existence of that function in other objects (thus to reduce other objects). Dynamic performance is used to segment the object to make every part of it can change its relative position. In case of an object is static as a whole, it can be made to move or moved. The characteristics of children's physiological, psychological and cognitive growth should be combined together to meet the design requirements of realizing the game experience, and nest is adopted to let an object pass through the cavity of another object. Reverse action is adopted to reverse the top and bottom, and inside and outside part of the object. Dynamic performance is used to segment the object to

make every part of it can change its relative position. In case of an object is static as a whole, it can be made to move or moved. The object or the performance of environment should be adjusted to make the object reach the best state at each working stage. Color change is used to change the color of the object or environment to arouse interest and cognition demands. In the design with the requirement of space saving, segmentation is used to divide an object into mutually independent parts. The object is divided into parts that are easy to disassemble and assemble. The degree of segmentation of the object should be deepened. Nest is used to insert an object into another, and insert the two combined objects into the third object, and so on. One object is let pass through the cavity of another object. Spatial dimension change is used to change the object arranging in one layer to the multilayer arrangement. The object shall be placed in an inclined or lateral position. The reverse side of the given surface can be utilized. On this basis, the design requirements and its corresponding TRIZ inventive principles of children's growth-oriented furniture are drawn, which are shown in Table 1.

Table 1. Design requirements and inventive principles of children's growth-oriented furniture

S/N	Design Requirements	Inventive principles
1	Safety and environmental protection	Local quality, prior action, precaution
2	Multi-function and growth potential	Segmentation, combination, versatility, dynamic performance
3	Game experience	Nest, reverse action, dynamic performance, color change
4	Space Saving	Segmentation, nest, spatial dimension change

3.2 Functional analysis of children's growth-oriented furniture based on the TRIZ theory

Functional analysis is an important tool for the TRIZ theory to analyze problems, which mainly recognizes problems that needs to be solved in later stages from the perspective of realizing the function and utility of the product. It mainly includes component analysis, transactional analysis and function modeling, extracting functional language from common expression.

3.2.1 Component analysis

According to the requirement and restriction of the project, component analysis can be divided as system and supersystem. In the system of children's growth-oriented furniture, the engineering system, namely children's growth-oriented furniture requires functions such as storage, growth potential, entertainment, safety, space saving, illumination, study. Therefore, according to the requirements of functions, the system components are set as the several parts of shelf, table, building block, blackboard, table leg, lamp, connecting component and stool. System components have the functions such as storage, operation, game, transformation, etc. Other components are super-systems, which, with system components, act upon and influence with each other. The supersystem components of the local engineering system refer to people and ground.

3.2.2 Transactional analysis

When two components contact each other, interaction will occur, and the research content of the transactional analysis refers to the interaction of mutual recognized components of the engineering system or supersystem. Whether there is connected relationship among various system components and supersystem components of children's growth-oriented furniture is shown in the chart with the symbols of "+" and "-". The former one indicates that there may be functions between the pair of components, and the specific function should be further analyzed, while the latter one indicates that there is no function between the pair of components, and the functional analysis of them can be excluded (Yu Fei, Tan Runhua, & Cao Guozhong, 2013).

4. Proposed design scheme of children's growth-oriented furniture

4.1 Analysis of contradictions and conflicts

The main existing technical contradictions and physical contradictions of the whole engineering system should be discussed through the establishment of the functional model of children's growth-oriented furniture, and contradictions and conflicts shall be elaborated and analyzed, as shown in Table 2. In the part of technical contradictions, the Altshuler Contradiction Matrix of the TRIZ theory is adopted to analyze and identify the inventive principle, so that to try to put forward the scheme for solving the technical contradictions, as shown in Table 3. The inventive

principle corresponding to the contradiction solution is marked in blue in the table. In the part of physical contradictions, solutions are proposed through the methods of separation, satisfaction and bypassing of contradiction requirements, as shown in Table 4.

Table 2. Table of children's growth-oriented furniture contradiction and conflict analysis

Type	Contradiction description	Parameter improvement	Parameter deterioration
Technical contradiction	Function number or type increase and operational usability decrease	Applicability and versatility	Operability
	Structure component number increase and stability decrease	Device complexity	Structure stability
	Structure component number increase and manufacturability decrease	Device complexity	Manufacturability

Table 3. Corresponding inventive principle of the Altshuler Contradiction Matrix

Deteriorated parameter		33	13	32
Improved parameter		Operability	Structure stability	Manufacturability
35	Applicability and versatility	15, 34, 1, 16	35, 30	1, 13, 31
36	Device complexity	27, 9, 26, 24	2, 22, 17, 19	27, 26, 1, 13

Table 4. Table of children's growth-oriented furniture physical contradiction and conflict analysis

Type	Contradiction description	Conflict object	Contradiction solution	Concrete solution	Inventive principle
Physical contradiction	More spaces are required in the process of using multi-functional furniture, so both the function and appropriate storage should be achieved.	Sizes of unfolded and folded state of the furniture	Satisfaction of contradiction requirements	Solve by the method of satisfaction	13, 36, 37, 28, 35, 38, 39
	The versatility and growth ability should conform to the physical characteristics of both children aged 3 to 5 and children aged 6 to 11.	Sizes of furniture used in different periods	Separation of contradiction requirements	Time separation	3, 10, 11, 15, 34

4.2 Solutions to contradictions of children's growth-oriented furniture

4.2.1 Solutions to technical contradictions

(1) In case of operational usability decrease due to function number or type increase, the inventive principle dynamic performance can be used to divide the system component into independent parts that are convenient for disassembly and assembly and the desktop of furniture can be made realize three functions of building block, desktop and blackboard. The desktop can be separated and cut according to the size of the building block desktop, which can be combined with the foundation of the desktop with the application of the nest method. The reverse side of the building block desktop can be taken as the desktop for writing, and can form an integral desktop for writing together with the foundation of the desktop after reversal, that is, the functions of writing and playing building blocks of the desktop can be realized through reversing the building block desktop. The blackboard is hung through reversing the whole desktop and connecting it with the shelf. The relative position of various parts of the three system components is changed to adjust components to make it reach the optimal state in each stage of work, as shown in Figure 2.

(2) The contradiction of stability decrease due to structure component number increase can be solved by the inventive principle extraction, merely extracting the necessary parts or attributes of the object. For example, since the system component is divided into various small components, small and thin wooden components that connecting different wooden parts are easy to be worn during usage. Therefore, hardware is applied to connect wooden parts, and the overall structure becomes more stable through matching with round logs with different lengths. The edges

of wooden parts should be polished as the round shape to prevent children from being injured by collision, improving the stability while enhancing the safety of the product.

Transformation of writing desktop, building block desktop and blackboard:



The storage box should be taken down the c should be reversed through grasping the groove the reversal is finished he blackboard is obtained through folding the blackboard

Figure 2. Technical solution 1 of children's growth-oriented furniture.

(3) The contradiction of manufacturability decrease due to structure component number increase can be solved by the inventive principle duplication. For example, through duplicating the connecting components, which are set as modules, and parents can change the position of modules with children's growth to change the height of desks and chairs. As children's growth and change, modules are added and reduced to satisfy children's requirements of height in different ages on the basis of ergonomics, which takes the full use of the adjustable principle, realizes multiple uses of one object and extends the service life of the product.

4.2.2 Solutions to physical contradictions

(1) More spaces are required in the process of using multi-functional furniture, so both the function and appropriate storage should be achieved. Solutions can be proposed with the help of the inventive principle, reversing the top and bottom, and inside and outside part of the object. For instance, magnetic accessories have been widely applied in children's furniture. The functions of entertainment and study can be realized through combining the blackboard and desktop and using table legs to support the desktop while using it. When it is only needed to use the table as the blackboard, the table legs can be removed through unscrewing them, and can be stored in the bottom part of the table by using buckles. The edges of the table board can be flipped inward to the angle of 90°, and the blackboard can be absorbed and connected with the shelf with the help of magnetic accessories, thus effectively saving the indoor space (Hu Kang, Zhang Jiren, & Ai Xianfeng, 2019).

(2) The versatility and growth ability should conform to the physical characteristics of both children aged 3 to 5 and children aged 6 to 12. It is advisable to use the inventive principle prior action to promote necessary changes of the object (the whole or at least parts of it) and set it in advance to make it play its role in the most convenient position. Various connecting components should be integrated. The elevation connecting component of the stool should be set at the top of the shelf, and the elevation component of the table should be taken as a part of the shelf when the child is at the age of 3-5. The position of the connecting component should be adjusted, that is, the height of the furniture should be changed to realize the integration of practicability and growth ability when the child grows to the age of 6-12.

4.3 Scheme output

The details of the design scheme of children's growth-oriented furniture should be improved, and then the complete design scheme can be output.

4.4 Model test

With the reference of the final design scheme, this study formulates a simple experimental model. The model mainly tests the feasibility of the combination mode between the connecting components and shelf, table legs, and stool legs, and determines whether it can satisfy the children's growth-oriented furniture's requirement of practicability and conform to the law of growth or not. The table board is reversed to verify the blackboard function under the folding mode, and the table legs are stored after being dismantled when changing the style of the table to verify the feasibility of the storage method and the operational difficulty of changing functions. To sum up, the final design scheme proposed in this study can help to achieve the expected effect, improve the efficiency of use and the

life cycle of children's furniture, which is feasible and practical.



Figure 3. Design scheme of children's growth-oriented furniture.

5. Summary

This study takes the development of children's growth-oriented furniture as an example, integrates users' requirements and the analysis based on the TRIZ theory, organizes the design and development work in the mode of determining problems, analyzing problems, solving problems and outputting solutions, and proposes design requirements from the perspective of user demand. Available inventive principles of children's growth-oriented furniture are explored, and functional analysis is conducted through using TRIZ tools, searching the solution from the perspective of component analysis, transactional analysis and graphical function model. In the stage of solving problems, contradictions and conflicts are discussed in two aspects of technicality and physical property to find the scheme for resolving contradictions. After outputting the scheme, the test is carried out in combination of the model prototype, and the feasibility of the engineering system and the operational difficulty are verified to return to the design process of user demand. The study verified that the design mode of combining the TRIZ theory with user requirement can solve the problems generated in the process of innovation and design of furniture, and can provide references for innovation and design of similar furniture products.

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