

Design and Evaluation of Children's Assembled Toys Based on Mortise and Tenon Structure and Zodiac Modeling

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Abstract: Toys are not only a way of entertainment for children, but also play an educational role. Toy products with Chinese local characteristics can not only help children experience excellent traditional culture, but also develop into cultural tourism products with local characteristics and promote the development of cultural industry. Based on the theory of children's cognitive development proposed by Swiss psychologist Jean Piaget in the mid-20 century, this study aims to improve the cognitive ability, self-awareness, movement and coordination ability of children aged 7 to 11 years. Based on the theory of multiple intelligences proposed by Howard Gardner, a contemporary American educational psychologist, the study is focused on design a set of children's assembled toys with Chinese traditional mortise and tenon structure and Chinese zodiac characteristics. The study is to provide references for the development of children's assembled toys with Chinese local characteristics.

Keywords: Children's Toys; The Mortise And Tenon Structure; Twelve Zodiac; Multi-Intelligence; Design Evaluation; Design Assessment

1. Introduction

The *Yi Jing Meng Gua* said: "The ignorant should be enlightened through education so that children will follow the right path." Out of the ancient Chinese Confucianism, children's education is of great importance - in the children's enlightenment stage to give the right education, in order to enlighten the wisdom, cultivate the temperament, nourish the temperament. Toys, as important items accompanying children's growth, should not

only serve the purpose of entertainment, but should also have an educational function. Since the 18 th National Congress, national leaders have repeatedly stressed the importance of ' cultural self-confidence ' and the creative transformation and innovative development of excellent traditional culture. Especially at the 20th National Congress, it was emphasized again to strengthen the inheritance and promotion of Chinese excellent traditional culture. This important instruction points out the direction for the development of children's toys with local characteristics.

However, the children's toys currently on the market are still mostly created based on cartoon characters and animals in European, American, Japanese and Korean styles, and their ethnicity and regionality are not prominent enough [1], and the few children's toys that embody certain local characteristics are mostly electronic products, which have failed to positively affect the cultivation of children's cultural self-confidence, visual health, motor perception and logical thinking, etc. [2]. Therefore, some domestic scholars are actively exploring how to develop and design assembled children's toys based on the "mortise and tenon structure" of traditional Chinese woodworking techniques to positively promote children's mental growth. Li et al. [3] pointed out that the design of the monolithic shape of the assembled toys was very critical, and the different levels of difficulty of the assembled toys could stimulate children's motivation to continue exploring and experimenting to varying degrees. Zhang [4] developed and designed a series of wooden assembled toys reflecting farming culture using mortise and tenon structure, Li et al. [5] developed a series of famous children's assembled toys reflecting landmarks using mortise and tenon structure,

and Zhao et al. [6] developed a series of toys reflecting the shape of the Lu Ban locks with different levels of difficulty by using mortise and tenon structure, and all of the above products have been well received by word-of-mouth evaluations. Through literature and market research, the design community generally believes that: (1) mortise and tenon structure has the unique advantage of live disassembly and assembly, which helps to cultivate children's hands-on ability and thinking ability [7]; (2) children are generally more interested in "figurative" modeling, especially animal modeling [8]. Based on this, this design tries to combine the mortise and tenon structure with the Chinese Zodiac, develop and design a set of from-easy-to-difficult, assembled toy products, in order to experience the traditional Chinese culture in the process of children's operation and play, improve their hands-on and perceptual ability, and provide a reference for the related enterprises in the development and design of new products.

2. Zodiac Puzzle Toy Design

2.1 Design Objects

Psychologist Piaget divided children's mental development into four stages: the perceptual-motor stage (0~2 years old), the preoperational thinking stage (2~7 years old), the concrete operation stage (7~11 years old), and the formal operation stage (12~17 years old), among which, in the concrete operation stage (7~11 years old), children's cognitive structure undergoes a significant change [9]. For example, their memory ability changes from the unconscious to conscious development, thinking with a certain degree of elasticity, and a preliminary understanding of three-dimensional space, which is the golden period for children to form a sense of teamwork and perceive the characteristics of objects. This program is designed for children at this stage, and it is expected to use toys as a carrier to help children aged 7~11 years old to build up a sense of the different geometric forms of traditional Chinese mortise and tenon construction, such as square, round, angle, column, etc., as well as the constructional forms of right-angled tenon, dovetail tenon and mortise and tenon

insertion, etc., so as to enhance their understanding of the traditional Chinese concepts of "yin and yang", "twelve Chinese zodiac signs", and "twelve Chinese zodiac signs". The program also enhances their recognition of traditional Chinese culture such as the "yin-yang unity" and the "twelve signs of the Chinese zodiac".

2.2 Program Design

This design takes the twelve Chinese zodiac shapes as the design source, draws out the characteristic distinctive modeling elements, takes the ears, horns, claws, rostrum and nasus of the Chinese zodiac animals as the characteristic points and surfaces, matches with the legs, claws, body and other straight or curved outer contours, forms the appearance design diagram as shown in Figure 1, and the modeling characteristics as shown in Table 1.



Figure 1. Appearance Design of Zodiac Assembled Toys

2.3 Structural Design

Based on Piaget's theory of children's mental development [10], children aged 7-11 years old should have the ability to deconstruct the form of an object to restore its original shape, in addition to the ability to recognize the overall shape of the object. Based on this, the above children's toy program is decomposed into a variety of structural forms based on right-angle mortise and tenon, dovetail, tenon

and other assembly parts, and according to the overall difficulty of assembly, divided into "Simpler-Moderate-Difficult" three

levels, the specific structural design program shown in Table 2.

Table 1. Characteristics of Chinese Zodiac Assembled Toys Modeling

Toy zodiac	Modeling features						Key characteristic parts
	Head	Ear	Rostrum	Nasus	Body	Tail	
Mouse	small	round, short, towering	small, sharp	convex	arciform	long, thin, curly	Ear, Rostrum, Tail
Cattle	large, with corners	flat	large, wide	convex	straight and strong	long, thick	Head, Rostrum, Body
Tiger	large, with 'Wang'	round, towering	moderate	flat	straight	long, thick	Head
Bunny	small	Oval, long, towering	small	flat	arciform	short, thick	Ear
Dragon	with horn	short, towering	moderate	convex	arciform, reel, with claw	long, thick, upwarping	Head, Body, Tail
Snake	small, oblate		small, with letter		reel, long	long, thin	Head, Rostrum, Body
Horse	large, with mane	short, towering	moderate	convex	straight	long, thick, hang	Head, Tail
Goat	small, with horn	short, fall	moderate	flat	straight	short, thick, hang	Head, Tail
Monkey	large	round, short, towering	large	flat	arciform	long, thin, reel	Ear, Tail
Rooster	small, with cockscomb		small		arciform, with claw	long, spreading, upwarping	Head, Body, Tail
Dog	small	apical, short, fall	moderate	convex	straight	short, thick	Ear
Hog	large	round, short, flat	large	convex, large	straight	short, thin	Ear, Nasus

Table 2. Zodiac Toy Mortise and Tenon Joint Information

Degree of difficulty	Zodiac	Overall size	Number of parts	Mortise and tenon joint styles
Simpler	Snake	118*128*105	15	Right angle single tenon, Walking horse sales
	Goat	92*53*46	13	
	Dog	101*34*53	13	
	Hog	98*72*53	10	
Moderate	Cattle	110*68*71	13	Right angle single tenon, Walking horse sales, Dovetail
	Tiger	119*65*60	15	
	Horse	100*29*87	16	
	Rooster	98*31*100	10	
Difficult	Mouse	100*36*76	11	Right angle single tenon, Right angle double tenon, Walking horse sales, Dovetail, Round tenon
	Bunny	117*70*105	11	
	Dragon	132*15*95	33	
	Monkey	128*80*139	12	

2.3.1 Simpler structural solutions

The Snake, Goat, Dog and Hog (Figure 2) are relatively easy to assemble, and they are all combined with right angle single tenon and walking horse sales. The right angle single tenon (Figure 3) consists of a convex and a concave mortise and tenon and best reflects the traditional cultural concept of 'the unity of yin and yang'. The walking horse sales (Figure 4) structure is formed by

embedding a raised pin with a groove. It is a combination of movement, in which a trapezoidal tenon is embedded into a groove consisting of a right-angled mortise and a trapezoidal mortise and tenon hole, which challenges the children's awareness of identifying different geometrical shapes, as well as their hand-eye coordination and fine-motor skills.

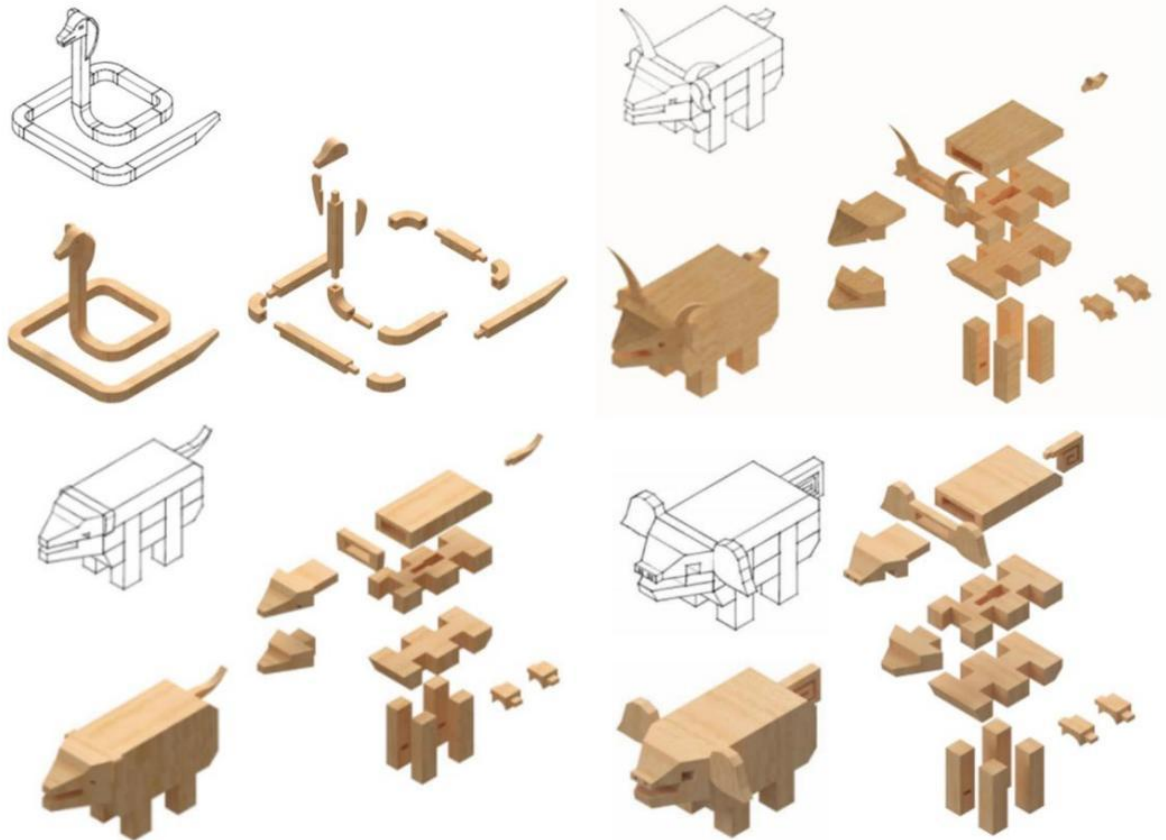


Figure 2. Snake, Goat, Dog and Hog Design Models

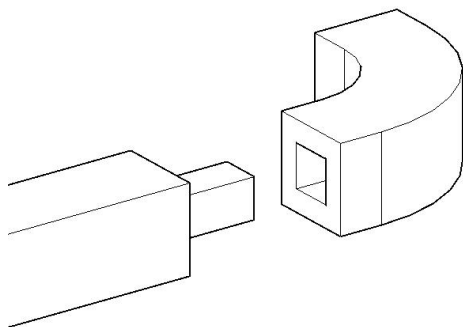


Figure 3. Right Angle Single Teno

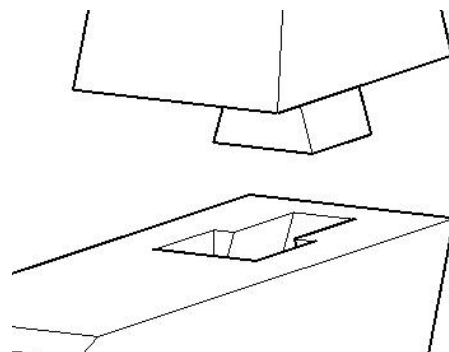


Figure 4. Walking Horse Sales

2.3.2 Medium structural program

The Cattle, Tiger, Horse and Rooster (Figure 5) are combined with right angle single tenon,

walking horse sales and dovetail. Dovetail (Figure 6) is a kind of joint with interlocking shape, which forms a stable mechanical structure through the interlocking of mortise and tenon groove. With the addition of dovetail structure, due to the different angles of the cheeks and shoulders of the tenon, the dovetail presents different modeling

characteristics and mechanical strength, and children can identify the relationship between different sizes and shapes of the material and the structural strength when playing with different forms of dovetails, further enhancing their structural perception and spatial imagination.

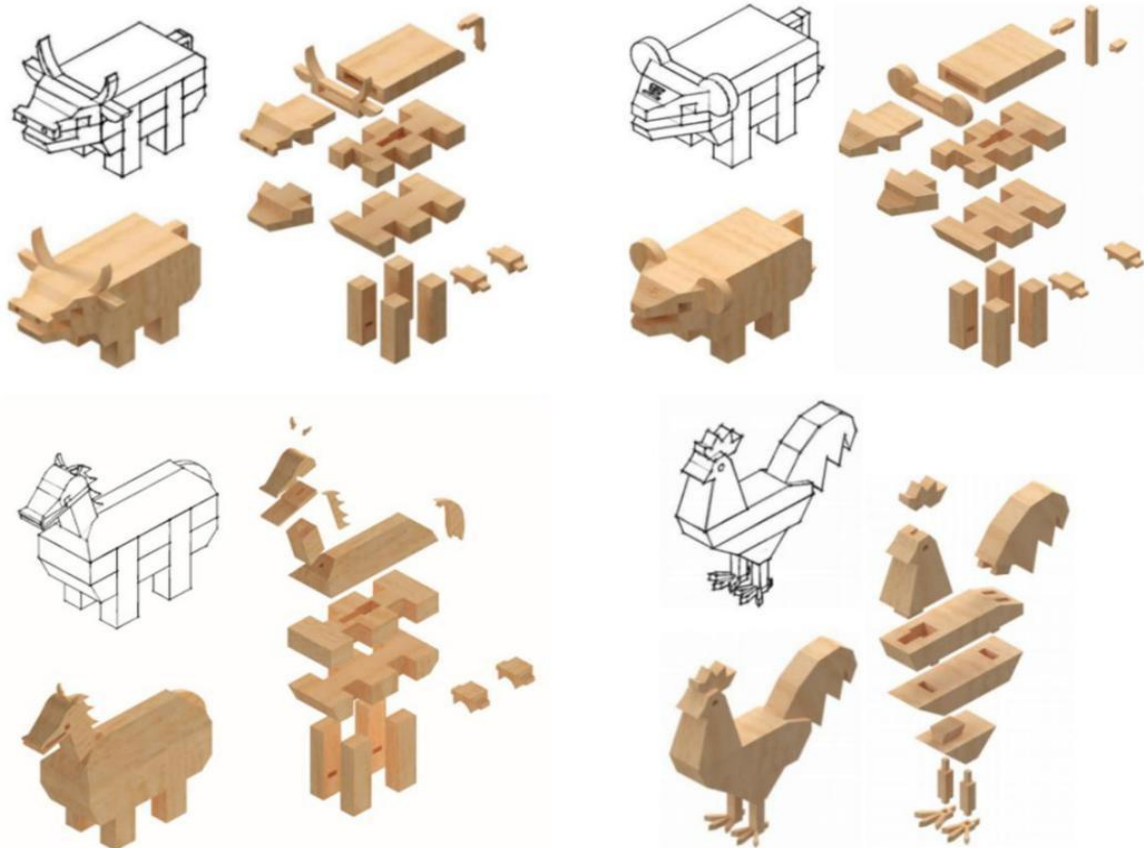


Figure 5. Cattle, Tiger, Horse and Rooster Design Models

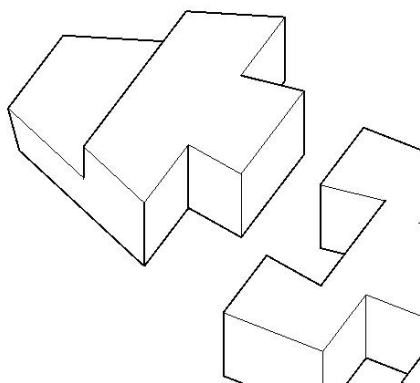


Figure 6. Dovetail

2.3.3 More difficult structural solutions

The Mouse, Bunny, Dragon and Monkey (Figure 7) are combined by right angle single tenon, right angle double tenon, walking

horse sales, dovetail, round tenon. The right angle double tenon (Figure 8) is to insert two square holes into the double right-angle tenon, and to improve the bonding strength of the piece by increasing the tenon bonding area. The round tenon (Figure 9) is to realize the embedding of parts by means of round tenon and round tenon eye. Due to the strong orientation of the right-angle double tenon and the high requirements on the installation direction of the parts and the lack of orientation of the single round tenon and mortise combination, both structures bring new challenges to the assembly of toys, and are more conducive to the cultivation of children's cooperative communication and spatial imagination.

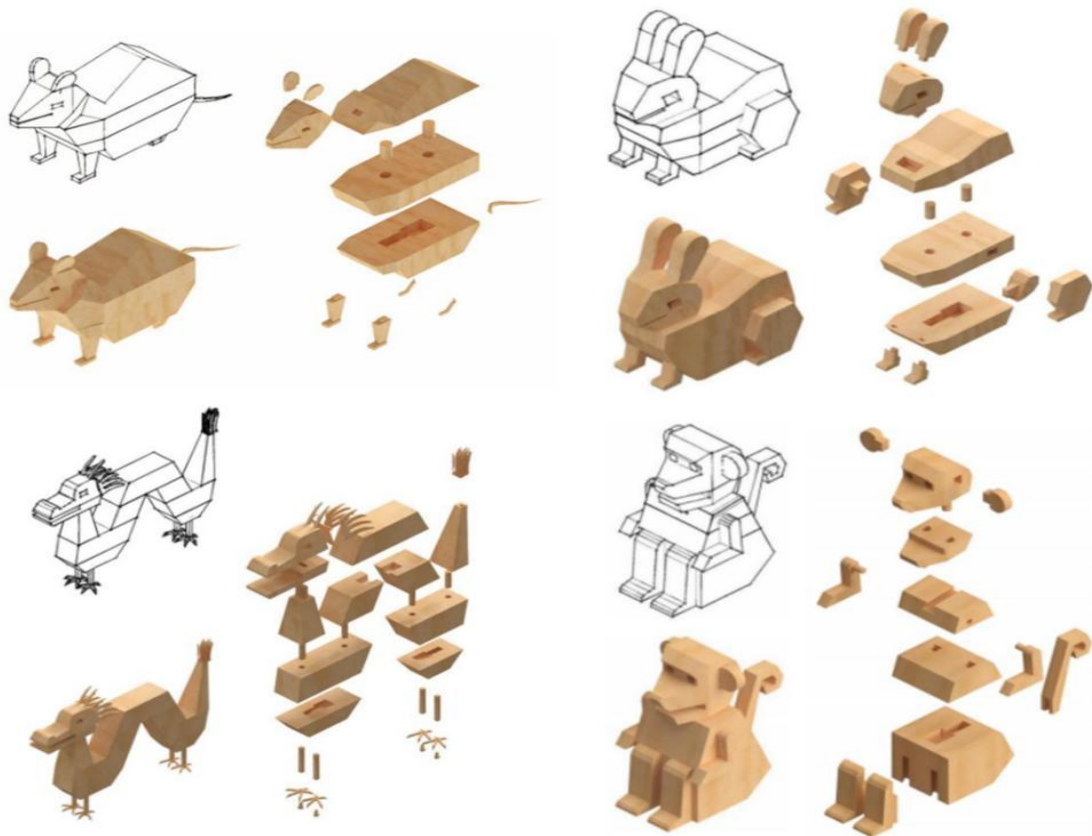


Figure 7. Mouse, Bunny, Dragon and Monkey Design Models

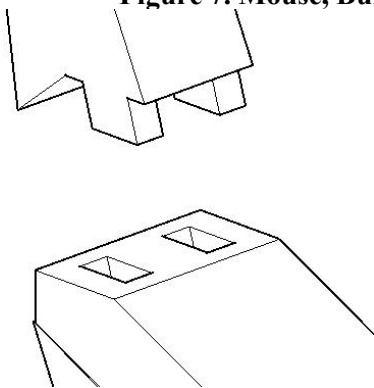


Figure 8. Right Angle Double Tenon

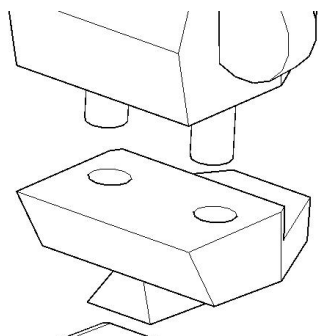


Figure 9. Round Tenon

3. Assessment of Design Options

3.1 Theoretical Foundations

Multiple Intelligences Theory is put forward by the American educator Howard Gardner. According to the theory, human beings have such eight intelligences as natural, introspective, interpersonal, linguistic, musical, spatial, logical, and motor ones, and these eight intelligences can be enhanced through acquired training, and a large number of scholars have already used the theory to evaluate the children's education [11,12]. Based on this, this design utilizes the theory of multiple intelligences to evaluate the designed children's toys, as shown in Table 3, which can help us to consider children's developmental needs in various intelligences more comprehensively, so that we can better provide children with suitable toys to promote their overall development in all aspects.

3.2 Evaluation Program

In order to understand the market prospects of this design program, an experience survey was conducted on 47 children aged 7~11 (23 boys and 24 girls) in the Xiangnan Children's Public Welfare Library in Fuzhou, and 30

social workers, parents, and teachers (adults) who were present at the library observed the children's performance during the assembly

process and communicated with the children, and evaluated the toys according to the 8 dimensions of Multiple Intelligences.

Table 3. Connotations of Multiple Intelligences and Their Use in This Design

Puzzle type	The connotation of multiple intelligences various intelligences [13]	The embodiment of multiple intelligences in this design
Natural intelligence	Refers to the ability to recognize and classify objects by observing nature in all its forms and to gain insight into natural or man-made systems.	Visualize nature and feel the texture of the toy material
Introspective intelligence	Refers to an individual's ability to recognize, gain insight into, and reflect on him or herself, characterized by sensitivity to one's own feelings and emotions, understanding one's own strengths and weaknesses, and using one's own knowledge to guide decision-making and set goals	Evaluate your ability to work with your hands and answer questions, and identify your shortcomings
Interpersonal intelligence	Refers to sensitivity to and the ability to respond effectively to the expressions, speech, and gestures of others, as evidenced by the individual's ability to perceive and respond appropriately to the emotions and feelings of others.	Improve children's ability to communicate and cooperate
Linguistic intelligence	Refers to a person's mastery of language and the ability to use it flexibly, as demonstrated by thinking in words and using language and words in many different ways to convey complex meanings	Improve children's ability to listen and communicate
Musical intelligence	Refers to the human ability to perceive, discriminate, remember, and express music, characterized by sensitivity to non-verbal sounds in the environment, including rhythm and tune, tempo, and pitch quality	Feel the crashing sound of wooden mortise and tenon toys as they are put together.
Spatial intelligence	Refers to a person's ability to correctly perceive and express the spatial location of colors and shapes, which is characterized by the ability to accurately perceive the visual world, produce thought images, think in three dimensions, and identify and perceive the connections between objects in space.	Enrich children's imagination of the appearance of objects by introducing them to the special construction of mortise and tenon.
Logical intelligence	Refers to a person's ability to express reasoning thinking with an understanding of logical consequence relationships, prominently characterized by problem solving using logical methods, having comprehension of numerical and abstract patterns, and recognizing applied reasoning for problem solving	Inspire children's understanding of graphic constructions and their ability to think deductively
Motor intelligence	Refers to the coordination, balance, and motor strength, speed, and flexibility of the human body, characterized by the use of the body for communication and problem	Train the ability to express thoughts and feelings with the body and improve body coordination

	solving, skillful manipulation of objects, and activities that require good motor skills
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3.3 Assessment of Results

The whole assessment process was scored using a five-point Likert scale, where 1 represents very dislike, 2 represents dislike, 3 represents average, 4 represents like, and 5 represents very like [14], and the five grades

reflect the observers' belief that children's eight intelligences are enhanced in the process of putting together toys, which provides a reliable data support for the study of children's toys' multiple intelligences (Table 4).

Table 4. Questionnaire Designed for Observers

Puzzle type	Questionnaire survey content	Overall score of observers
Natural intelligence	Ability for children to visualize wood grain	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Introspective intelligence	Ability to make children aware of their shortcomings	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Interpersonal intelligence	Whether it improves children's ability to communicate and cooperate	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Linguistic intelligence	Whether it improves children's language expression and listening skills	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Musical intelligence	Whether it enables children to perceive the non-verbal sounds of wooden toys colliding with each other	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input checked="" type="checkbox"/> Generally <input type="checkbox"/> Liked <input type="checkbox"/> Liked very much
Spatial intelligence	Whether it stimulates children's structural perception and spatial imagination	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Logical intelligence	Whether it can improve children's knowledge of different geometric shapes and correctly put together toys.	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much
Motor intelligence	Whether it can improve children's hand-eye coordination and fine motor skills	<input type="checkbox"/> Disliked very much <input type="checkbox"/> Disliked <input type="checkbox"/> Generally <input type="checkbox"/> Liked <input checked="" type="checkbox"/> Liked very much

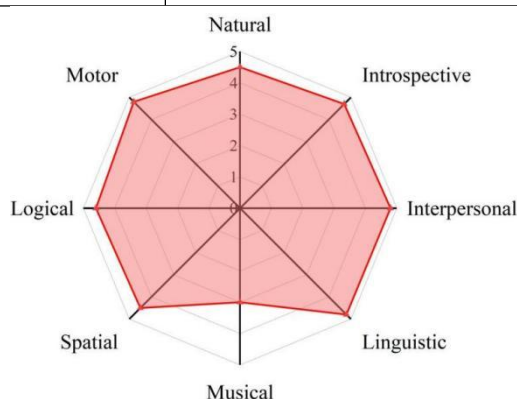


Figure 10. Observers' assessment Feedback based on the Theory of Multiple Intelligences

Based on the analysis of the overall feedback from 40 observers on the children's assembling of the twelve pieces of mortise-and-tenon construction of the Chinese zodiac toys (Figure 10), the design to some extent promoted the hand-eye coordination and fine motor skills of children aged 7 to 11. By setting up levels of difficulty in assembling, children faced challenges in completing the assembly process, cultivated their limited abilities, and took the initiative to seek help from classmates and parents, which increased children's opportunities to communicate and learn from others. In addition, the animal-like appearance and various mortise and tenon structures of the toys stimulate children's

4. Conclusions and Outlook

structural perception, spatial imagination and cognitive ability to recognize various geometric shapes. At the same time, the design enhances children's sense of identity with the traditional Chinese culture of "yin and yang" and the "twelve signs of the Chinese zodiac". It is important to note that the design is an assembled toy, not a percussive toy, and therefore the degree of stimulation of children's musical intelligence is relatively low.

With the development of the times and the advancement of science and technology, children's toys that only contribute to "intellectual development" can hardly meet the expectations of both parents and children. Based on Piaget's theory of children's cognitive development, this design combines mortise and tenon construction with the Chinese zodiac culture to create a set of children's toys. After the evaluation and analysis by observers based on the theory of multiple intelligences, it is proved that the design can positively promote the eight intelligences of children aged 7 to 11, including natural, introspective, interpersonal, linguistic, musical, spatial, logical and motor intelligences. In the development and design of children's toys, designers should fully consider children's growth stage, thinking characteristics, cognitive level and experience needs, and follow the principle of "from shallow to deep, step by step, appropriate segmentation and spiral". In the future, we can also design a series of disassembled toys for different years of the Chinese Zodiac, based on one of the twelve zodiac signs. For instance, the "dragon" assembled toys reflect the growth process of the dragon and the changes in the shape of the dragon in different times, thus cultivating students' hands in a deeper fashion. This will help students to develop their hand, eye and brain coordination and their knowledge and understanding of traditional Chinese culture.

Acknowledgment

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