

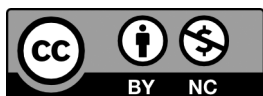
# The Effectiveness of Integrating Luban Locks into Kindergarten Activities: An Empirical Study on Promoting the Scientific and Social Development of Senior Preschoolers

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**Abstract:** To implement the requirements of cultivating inquiry abilities in the scientific domain and communication skills in the social domain as stipulated in the Guidelines for the Learning and Development of Children Aged 3-6 Years, while inheriting excellent traditional Chinese culture, this study designed and implemented an integrated activity titled “Harmonious Little Craftsmen: The Harmonious Home of Luban Locks” for the science and social domains in senior preschool classes, using Luban Locks as the carrier. A total of 100 senior preschoolers from a kindergarten in Shuangliu District, Chengdu, were selected as research participants. A self-developed evaluation questionnaire was used to conduct pre-tests and post-tests across four dimensions. The results showed that after the experiment, children’s scores in traditional cultural philosophy ( $14.33 \pm 2.73$ ), systematic thinking ( $14.44 \pm 3.01$ ), natural ecological awareness ( $16.11 \pm 2.56$ ), and craftsmanship spirit ( $15.56 \pm 2.78$ ) were significantly higher than those before the experiment ( $p < 0.01$ ). The result demonstrates that this integrated activity not only promotes the coordinated development of children’s scientific inquiry skills and social communication competencies but also contributes to the transmission and enlightenment of traditional culture. Furthermore, it offers practical implications for the design and implementation of interdisciplinary learning activities in early childhood education settings.

**Keywords:** Interdisciplinary integration; Luban Locks; traditional cultural enlightenment; Preschooler development assessment



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## 1 Introduction

Educational toys, as tools with both entertaining and educational functions, play a crucial role in children’s

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cognitive development (Saikia, 2023). They are designed to enhance children's intelligence, creativity and higher-order thinking abilities (Hogle, 1996), combining educational and recreational functions. Through the game process, such toys promote children's concept formation and cognitive growth, and offer multiple values, including stimulating functional development, coordinating physical functions, and cultivating social skills (Deborah, 2006; Elkind, 2008).

Among the wide variety of educational toys, the Luban Lock (Figure 1) — a representative traditional Chinese educational toy— originated from the mortise and tenon structure in ancient Chinese architecture (Fu & Chen, 2021; He et al., 2020; Liu & Leng, 2019; Ying, 2016). It forms a stable structure through the interlocking of concave and convex parts of wooden pieces, without the use of nails or rivets, thereby embodying the craftsmanship and mathematical thinking of ancient people (Yang et al., 2022; Zhang et al., 2017). The Luban Lock itself integrates scientific inquiry and social cooperation: the mortise and tenon structure serves as a natural material for children to explore the relationship between parts and the whole, while the assembly process inevitably fosters negotiation, division of labor, and cooperative behaviors (Shang et al., 2025; Tanaka et al., 2014). This carrier characteristic, which embeds scientific principles in objects and integrates social rules into activities, realizes in-depth integration and mutual promotion between the two domains. It holds important theoretical value and practical significance for promoting the innovation and development of preschool education in the context of cultural confidence in the new era.



Figure 1 The Externals of Luban Locks

## 1.1 The Application of Luban Locks in Education

The Luban Lock, also known as Kongming Lock, is an educational toy that originates from the mortise and tenon structure of ancient Chinese architecture (Ying, 2016). Its basic mechanism involves interlocking concave and convex wooden components to create a stable, three-dimensional structure without the need for nails or other external fasteners (Song & Ni, 2009; Zhao & Dong, 2021). This unique structural feature makes it an ideal teaching aid for cultivating spatial cognitive abilities and logical thinking abilities. As a representative of traditional Chinese educational toys, the unique mortise and tenon structure of the Luban Lock contains rich educational value. In recent years, with the popularization of the STEM education concept and the emphasis on traditional cultural education (Wu & Tseng, 1985; Xie et al., 2015), the educational value of Luban Locks has gradually attracted attention, becoming a bridge connecting traditional wisdom with modern education. In the preschool education stage, due to its high operability and ingenious structure, the Luban Lock is considered conducive to developing preschoolers' spatial cognitive abilities and hands-on operational abilities. In practical educational applications, Luban Lock activities usually adopt the theoretical framework of Situated Learning, embedding learning content into meaningful real-world problem scenarios. Yiqing Tong (2023) has shown that through operating Luban Locks, preschoolers can intuitively perceive mathematical concepts such as geometric shapes and symmetrical relationships, while cultivating patience and concentration during the assembly

and disassembly process. This “learning by doing” method enables students to construct knowledge through practical operations, promoting the unification of concept understanding and skill development (Schank et al., 1999). However, existing studies mostly focus on the application of Luban Locks in a single domain and insufficiently explore their potential value in interdisciplinary integration.

## 1.2 Practical Status of Integration between the Scientific and Social Domains

In the current reform of preschool education, domain integration has become an important development direction. The Guidelines for the Learning and Development of Children Aged 3-6 Years (2012) explicitly emphasize the mutual integration of content across various domains. The integration of the scientific and social domains holds special significance: scientific inquiry activities often require cooperative completion, while the development of social communication skills also needs to be realized in specific activities. Nevertheless, existing practices have problems such as insufficient depth of integration and a lack of systematicness in activity design. Some activities simply piece together content from different domains, failing to achieve true organic integration. As a highly integrative and hands-on educational medium, the assembly process of the Luban Lock involves both the understanding of scientific concepts, such as spatial geometry and physical structures, and the application of social skills, such as communication, collaboration, and problem-solving, thereby providing a natural context for interdisciplinary learning. This situation makes exploring effective interdisciplinary activity models an important issue in current preschool education practice.

## 2 Method

### 2.1 Participants

This study selected 100 preschoolers from 4 senior classes of a kindergarten in Shuangliu District, Chengdu, as research participants, including 52 males and 48 females. Their ages ranged from 5 to 6 years. All participants had no special educational needs, and prior communication and consent were obtained from the kindergarten. The rationality of the sample size was calculated using G\*Power 3.1 software. According to Faul et al. (2009), the expected effect size was set to a medium level ( $d_z = 0.5$ ), the significance level ( $\alpha$ ) was set to 0.05 (one-tailed test), and the target value of statistical power ( $1-\beta$ ) was set to 0.95, meaning the study required a 95% probability of detecting a truly existing effect (Cohen, 1988). The calculation results showed that the minimum sample size required for the study was 54. To account for potential participant attrition and invalid data, and in line with recommendations for ensuring robust power (Lakens, 2013), the final sample size was expanded to 100 to ensure the study had extremely high statistical power and provide more sufficient guarantees for data stability and result generalizability.

### 2.2 Design

A self-developed Questionnaire for Evaluating Luban Lock Integrated Activities in Senior Preschool Classes was used for assessment in this study (Table 1), which includes four dimensions: traditional cultural philosophy, systematic thinking, natural ecological awareness, and craftsmanship spirit, with a total of 16 evaluation indicators. A 5-point Likert scale was adopted, with a total score ranging from 0 to 80, which was later converted to a 100-point

scale. The Cronbach’s alpha coefficient was used to test the reliability of the questionnaire. The results showed that the alpha coefficient of the questionnaire was 0.882, indicating good internal consistency and measurement reliability (Madore et al., 2025; Offit et al., 2013). Exploratory factor analysis was used to test the construct validity of the questionnaire. The KMO value was 0.818, and the Bartlett’s test of sphericity was significant ( $\chi^2 = 720.501$ ,  $df = 120$ ,  $p < 0.001$ ), indicating that the data were suitable for factor analysis (Padhy et al., 2024). The principal component analysis method was used to extract four factors with eigenvalues greater than 1, and the cumulative variance explained rate was 65.49%. The rotated factor loading matrix showed that each item had clear loadings on the corresponding factors, with a clear factor structure, verifying the good construct validity of the questionnaire.

However, it is important to note that this study employed a cross-sectional design with the self-developed questionnaire, which primarily captures associations and perceptions rather than establishing causal relationships. The findings should be interpreted as reflecting correlations and trends within the specific context of the study. Future research could benefit from longitudinal or experimental designs to further explore causal inferences regarding the impact of Luban Lock integrated activities on child development.

Table 1 Questionnaire for Evaluating Luban Lock Integrated Activities in Senior Preschool Classes

Evaluation Dimension	Evaluation Indicators
Traditional Cultural Philosophy	Under the teacher’s guidance, students can identify the concave-convex relationship between the mortise and tenon structures of the Luban Lock
	Can describe how Luban Lock components form an overall structure through combination, and understand that parts affect the stability of the whole
	Shows patient collaboration during assembly, reflecting the awareness of harmony in diversity
	Shows interest in the historical background of the Luban Lock and can retell its simple cultural significance
Systematic Thinking	Can observe and distinguish the shapes of different wooden strips and the positions of grooves, and accurately match mortise and tenon structures
	Attempts to assemble step by step, can identify errors and adjust the sequence
	Can find solutions through observing others and repeated attempts
	Understands the idea that “a single move affects the whole” during the disassembly process
Natural Ecological Awareness	Can notice that the Luban Lock is made of wood and state that it is wooden
	Takes the initiative to care for materials, handles them gently, and does not randomly damage or waste wooden strips
	Attempts to conform to the properties of wood during assembly, does not press forcefully, and uses grooves for natural fitting
	Understands the environmental significance of being detachable and reconfigurable
Craftsmanship Spirit	Maintains concentration during assembly, does not give up easily, and continues exploration for at least 1 minute
	Attempts to align mortise and tenon grooves accurately, focusing on details
	Does not get impatient when encountering difficulties, and tries different combinations multiple times; shows a sense of pride in completing the work
	Shows interest in the process of artisans making Luban Locks and is willing to imitate traditional manual operations

### 2.3 Procedures

Based on constructivist learning theory and social interdependence theory (Johnson & Johnson, 2005; Zajda, 2021), and following the learning characteristics of senior preschoolers aged 56 (such as dominant concrete thinking, critical development of fine motor skills, and emerging sense of cooperation), this study constructed a four-stage activity process: scenario introduction, independent exploration, cooperative construction, and summary extension. A pre-test and post-test design was adopted, with an implementation cycle of two weeks. Each activity lasted 30 minutes and was organized by trained teachers and students. First, a story with emotional appeal titled “The Harmonious Home

of Small Animals” was used for scenario introduction, endowing the operation of Luban Locks with clear task sense and significance to stimulate children’s intrinsic motivation. Second, in the independent exploration stage, children gained a personal perception of the shape differences of components and the concave-convex structural relationship of mortise and tenon by observing, touching, and attempting to assemble and disassemble a single Luban Lock, initially establishing scientific cognition of structure and function. Subsequently, the activity entered the core cooperative construction stage, where children were divided into groups and required to clarify their division of labor through negotiation to jointly complete a collective work of “harmonious home”. During this process, teachers helped children learn cooperation strategies and solve conflicts through strategic questioning and demonstration guidance, enabling them to deeply understand the necessity of division of labor and collaboration for achieving common goals. Finally, in the summary and extension stage, teachers not only guided children to reflect on the cooperation process but also clarified the wisdom of ancient Chinese artisans embodied in the Luban Lock, realizing the sublimation of cultural significance.

### 2.4 Data Analysis

SPSS 26.0 was used for data analysis (Cronk, 2016). The pre-test was completed one week before the start of the activity, and the post-test was conducted immediately after the activity ended. Paired-samples t-tests were used to compare differences between pre-test and post-test (Ross & Willson, 2017), and Pearson correlation analysis was used to examine the relationships between various dimensions (Cohen, 1975). The significance level was set to 0.05.

## 3 Results

Data analysis showed that the integrated activity had an extremely significant positive impact on children’s development (Table 2). First, in terms of overall development level, children’s post-test total scores (80.54±9.74) were extremely significantly higher than pre-test scores (66.39±6.86),  $t = 17.117, p < 0.001$ .

Table 2 Total Scores before and after the Experiment

Item	Mean	Standard Deviation	t
Pre-test Total Score	66.390	6.858	
Post-test Total Score	80.540	9.739	17.117***

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Second, in terms of specific development in each dimension, the activity brought significant improvements (Table 3): the post-test score of traditional cultural philosophy (14.33±2.73) was significantly higher than the pre-test score (11.89±2.45) ( $p < 0.001$ ). Specifically, children could not only identify the mortise and tenon structure of the Luban Lock but also describe the relationship between parts and the whole under the teacher’s guidance, show patience and collaboration during assembly, and exhibit a stronger interest in the historical and cultural background of the Luban Lock. The post-test score of systematic thinking (14.44±3.01) was also significantly higher than the pre-test score (12.04±2.56) ( $p < 0.001$ ). Children demonstrated stronger abilities to observe, distinguish, and match mortise and tenon structures during the activity, could assemble step by step and actively adjust strategies when making mistakes, and were more able to initially understand the systematic idea of “a single move affects the whole” during the disassembly process. Although the pre-test baseline of natural ecological awareness was relatively high, the post-test score (16.11±2.56) still showed a statistically significant improvement ( $p = 0.007$ ). Children not only took more initiative

to care for wooden materials and handle them gently, but also attempted to conform to the properties of wood for natural fitting during assembly, and gained a deeper understanding of the environmental significance of the Luban Lock being detachable and reconfigurable. The post-test score of craftsmanship spirit ( $15.56 \pm 2.78$ ) increased significantly ( $p < 0.001$ ). Children’s concentration and persistence during operation were significantly enhanced, giving up behavior decreased when encountering difficulties, they were more inclined to try different solutions multiple times, and showed a significant sense of pride and accomplishment after completing the work.

Table 3 Paired Samples Statistics (N = 100)

		Standard Deviation of Paired Differences	Standard Error of Mean of Paired Differences	95% Confidence Interval of Paired Differences - Lower Bound	95% Confidence Interval of Paired Differences - Upper Bound	t	Significance (Two-tailed)
Pair 1	Pre-test Traditional Cultural Philosophy - Post-test Traditional Cultural Philosophy	2.979	0.298	-3.031	-1.849	-8.190	0.000
Pair 2	Pre-test Systematic Thinking - Post-test Systematic Thinking	2.558	0.256	-2.908	-1.892	-9.381	0.000
Pair 3	Pre-test Natural Ecological Awareness - Post-test Natural Ecological Awareness	1.134	0.113	-0.535	-0.085	-2.733	0.007
Pair 4	Pre-test Craftsmanship Spirit - Post-test Craftsmanship Spirit	1.726	0.173	-1.372	-0.688	-5.968	0.000

More importantly, correlation analysis revealed the synergy of ability development across various dimensions. Pearson product-moment correlation analysis (Table 4) showed that there were significant positive correlations between the four dimensions after the experiment ( $r = 0.48-0.69, p < 0.01$ ). This indicates that the progress of children in traditional cultural philosophy is closely related to the enhancement of their systematic thinking abilities, the cultivation of craftsmanship spirit, and the emergence of ecological awareness, promoting each other. This finding strongly supports the core concept of interdisciplinary integrated education, that children’s development is holistic, and abilities in different domains can achieve coordinated progress in an integrated activity.

Table 4 Pearson Product-Moment Correlation

		Post-test Traditional Cultural Philosophy	Post-test Systematic Thinking	Post-test Natural Ecological Awareness	Post-test Craftsmanship Spirit
Post-test Traditional Cultural Philosophy	Pearson Correlation	1			
	Significance (Two-tailed)				
	Number of Cases	100			
Post-test Systematic Thinking	Pearson Correlation	0.692**	1		
	Significance (Two-tailed)	0.000			
	Number of Cases	100	100		
Post-test Natural Ecological Awareness	Pearson Correlation	0.480**	0.596**	1	
	Significance (Two-tailed)	0.000	0.000		
	Number of Cases	100	100	100	
Post-test Craftsmanship Spirit	Pearson Correlation	0.637**	0.625**	0.659**	1
	Significance (Two-tailed)	0.000	0.000	0.000	
	Number of Cases	100	100	100	100

Note: \*\* $p < 0.001$ .

## 4 Discussion

The results of this study confirm the effectiveness of Luban Lock integrated activities in promoting children's development. From the perspective of scientific literacy development, the mortise and tenon structure of the Luban Lock provides preschoolers with a physical carrier for exploring geometric shapes, symmetrical relationships, and physical structures. During the assembly and disassembly process, children need to observe the concave-convex features of wooden strips and analyze the connection relationships between various parts, which promotes the development of spatial cognitive abilities and logical thinking abilities. From the perspective of social development, the process of collaborative construction creates an authentic social interaction context, encouraging communication, negotiation, and shared problem-solving among peers (Johnson & Johnson, 2005). When working in groups, children engage in negotiating the division of labor, exchanging ideas, and solving conflicts. These interactive behaviors promote the development of communication skills, collaborative spirit, and problem-solving competence, while also cultivating children's sense of cultural identity and craftsmanship. Moreover, through its design principles — which integrate teaching into narrative contexts, embed knowledge into hands-on practice, and infuse culture into collaborative inquiry — this study offers a practical and evidence-based model for addressing two key challenges in preschool education: the effective transmission of traditional culture and the implementation of interdisciplinary integration. It is worth noting that the correlations between various dimensions indicate the integrity of children's development. The high correlation between traditional cultural philosophy and systematic thinking ( $r = 0.69$ ) shows that the understanding of traditional culture is closely related to the development of logical thinking abilities. The correlation between craftsmanship spirit and natural ecological awareness ( $r = 0.66$ ) indicates that the cultivation of qualities such as concentration and patience is synergistic with the formation of environmental awareness. This finding supports the core concept of interdisciplinary integrated education, children's development is a holistic process, and abilities in different domains can achieve coordinated progress in integrated activities, promoting the development of children in multiple aspects simultaneously. This is consistent with the current educational concept that emphasizes all-around development. However, the study also found that there were individual differences in the activity, and some children encountered difficulties in the independent operation stage. This phenomenon reminds us to further optimize the activity design and provide more personalized support. Based on the selection principles of cognitive toys, it is advisable to offer Luban Lock materials with varying levels of difficulty to accommodate children's diverse abilities, thereby ensuring that each child encounters optimal challenges within their zone of proximal development (ZPD) (Harland, 2003).

## 5 Conclusion

The study shows that the integrated activity with Luban Locks as the carrier can effectively promote the coordinated development of scientific literacy and sociality of senior preschoolers. The study not only confirms the effectiveness of Luban Lock integrated activities but also forms a complete example from theoretical construction and activity design to effect evaluation. This activity model provides preschoolers with rich learning experiences and offers a feasible path for the innovative application of traditional culture in preschool education. It reveals that excellent traditional cultural materials themselves contain wisdom for solving modern educational dilemmas. Future studies can further explore the

optimization strategies of the activity plan and its applicability in kindergartens with different backgrounds, providing a more practical basis for promoting the all-around development of preschoolers.

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