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# Design and Development of a Liushu-Based Interactive Game for Chinese Character Learning: A Game Mechanics–Driven Approach

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### Abstract

This study presents the design and development of a Liushu-based interactive game for Chinese character learning, employing a game mechanics–driven approach to transform linguistic theory into meaningful learning interactions. The proposed system integrates principles of the Liushu (六书) theory with core game mechanics, including character structure decomposition, classification-based gameplay, progressive challenge levels, and immediate feedback loops, in order to support structural understanding and learner engagement. Grounded in cognitive learning theory and game-based learning principles, the design positions game mechanics as the central mechanism through which learners interact with and internalize Chinese character knowledge. The system was implemented as an interactive learning application for upper secondary school students, and a preliminary evaluation using a one-group pretest–posttest design was conducted to examine the feasibility and educational potential of the proposed approach. The results showed substantial gains in conceptual understanding and high levels of learner engagement and satisfaction, providing supportive evidence that theory-driven game mechanics can effectively scaffold Chinese character learning. The primary contribution of this work lies in (1) a Liushu-to-game-mechanics mapping, (2) a game mechanics–driven design framework that links linguistic theory, cognitive processes, and game mechanics, and (3) a fully implemented playable system that demonstrates the practicality of the framework in real classroom contexts.

**Keywords:** Chinese character learning, Liushu theory, game-based learning, structural awareness

### ■ Introduction

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## Background

Chinese has increasingly become one of the most important global languages in education, communication, and economic exchange, leading to a continuous rise in the number of learners worldwide (Wang et al., 2024; Ministry of Education of the People's Republic of China, 2023). Despite this growth, Chinese character learning remains a major challenge, particularly for learners whose first language is based on alphabetic systems (Shen, 2005; Everson, 2011). Unlike phonetic writing systems, Chinese characters are logographic and structurally complex, requiring learners to simultaneously process form, meaning, and, in many cases, sound (Packard, 2000; Hoosain, 1991). As a result, traditional instructional approaches that rely heavily on rote memorization and repetitive writing often lead to superficial learning, low retention, and decreased learner motivation (Ke, 1998; Sung & Wu, 2011).

To address these challenges, researchers have increasingly explored game-based learning as a means of enhancing learner engagement and promoting more interactive learning experiences (Prensky, 2001; Gee, 2003; Hamari et al., 2016). However, many existing Chinese language learning applications, such as Duolingo, HelloChinese, Hanzii, and ChineseSkill, primarily focus on vocabulary learning through matching exercises, multiple-choice activities, and repetition-based practice. While these approaches support vocabulary acquisition and memorization, they provide limited opportunities for learners to develop an understanding of Chinese character structures and the principles underlying character formation (Li, 2022; Zhao & Chen, 2023).

Furthermore, many existing applications adopt gamification strategies by incorporating points, badges, levels, and achievement systems to increase motivation. Although these elements can improve learner engagement, the game mechanics themselves are rarely designed to support structural understanding of Chinese characters. As a result, learners may memorize vocabulary successfully while still lacking an understanding of how Chinese characters are constructed and how their meanings are derived.

While gamification and game-based learning are often discussed together, they represent different approaches to learning design. Gamification typically incorporates game elements such as points, badges, rewards, and progression systems to increase learner motivation, while the learning content itself remains largely unchanged (Kapp, 2012). In contrast, a game mechanics-driven approach embeds learning objectives directly within gameplay interactions. Under this approach, learners acquire knowledge through actions, decisions, and problem-solving processes that are intentionally aligned with learning goals. Consequently, learning occurs through gameplay itself rather than through external motivational features alone.

Liushu (六书) theory has long been recognized as an important framework for explaining Chinese character formation and the relationships among character forms, meanings, and structural components (Xu Shen, trans. 1963; Qiu, 2000). Previous studies have shown that structural awareness can significantly enhance learners' ability to analyze, memorize, and interpret Chinese characters (Shen & Ke, 2007; Taft & Chung, 1999). In the context of Chinese character learning, the first four Liushu categories—pictographic characters (象形), indicative characters (指事), associative compound characters (会意), and phonetic-

semantic compound characters (形声)—are particularly valuable because they clearly illustrate structural relationships and can be transformed into interactive learning activities (Lu Jun Fang, 2022).

In the present study, Liushu theory serves not only as instructional content but also as a theoretical foundation for game mechanics design. The structural characteristics of different character categories inform the design of specific learner interactions. For example, pictographic characters support image–meaning association activities, indicative characters support classification and interpretation tasks, associative compound characters encourage component analysis, and phonetic-semantic compound characters promote the identification of semantic and phonetic components. In this way, gameplay mechanics are derived directly from the structural principles of Chinese character formation, allowing learners to construct knowledge through interaction rather than memorization alone.

To address the limitations of existing approaches, this study adopts a game mechanics–driven design approach to develop an interactive Chinese character learning application called *Secret of Hanzi*. Unlike conventional applications that use game elements primarily as motivational features, the proposed system integrates Liushu theory directly into gameplay interactions. The structural characteristics of different character categories are translated into learning activities that promote structural analysis, knowledge organization, and meaningful learning. The objectives of this study are threefold: (1) to design a Liushu-based interactive game that systematically translates linguistic theory into game mechanics, (2) to develop an operational learning system that supports structural understanding of Chinese characters through gameplay, and (3) to examine the feasibility and educational potential of the proposed approach through preliminary implementation. By focusing on the relationship between learning theory and game mechanics, this study contributes a design-oriented framework for integrating linguistic theory with game-based learning in language education.

## ***Contribution of the Study***

### ***Theoretical Contribution***

This study contributes to the theoretical understanding of game-based learning for Chinese character education by proposing that Liushu Theory (六书) serves not only as instructional content but also as a theoretical foundation for game mechanic design. For example, phono-semantic compound characters (形声字) generally consist of two components: a semantic component, known as the semantic radical (形符) or semantic indicator (形旁), and a phonetic component, known as the phonetic radical (声符) or phonetic indicator (声旁). For instance, the characters 江 (river) and 河 (river) both relate to water and therefore share the semantic component 氵, while 工 and 可 function as phonetic components indicating pronunciation. Based on this structural principle, this character category was transformed into the “Learning Sounds through Character Structure” game, in which learners analyze character components and classify them into semantic and phonetic elements through a drag-and-drop activity. This mechanic promotes learners’ understanding of internal character structures and the

relationship between meaning and pronunciation. More broadly, the study demonstrates how the principles of Chinese character formation can be systematically translated into interactive gameplay activities aligned with learning processes. Furthermore, it establishes a theoretical linkage among linguistic theory, cognitive learning principles, and game mechanics, providing a foundation for theory-driven educational game design.

### *Design Contribution*

This study proposes a Game Mechanics–Driven Design Approach that explicitly connects Liushu categories with corresponding game mechanics. Pictographic characters (象形字), which originate from visual representations of objects found in nature, were translated into the Matching Meaning Game, where learners match Chinese characters with corresponding images to strengthen visual associations between form and meaning. Indicative characters (指事字), which use symbols or markers to represent abstract concepts or spatial relationships, were transformed into the Basket of Meaning Game, in which learners categorize characters according to their meanings and conceptual relationships. Associative compound characters (会意字), which combine two or more components to create new meanings, were implemented in the Character Formation Game, where learners analyze character components and identify the correct explanation of how a character was formed. Finally, phono-semantic compound characters (形声字), which consist of semantic and phonetic components, were implemented in the Learning Sounds through Character Structure Game, where learners identify and classify semantic and phonetic elements within characters. This design approach demonstrates how domain-specific knowledge structures can be transformed into meaningful learning interactions and provides a reusable framework for future educational game development.

### *System Contribution*

This study develops and implements the Secret of Hanzi interactive learning system as a practical realization of the proposed design framework. The system integrates Liushu-based content, game mechanics, immediate feedback, progression systems, and interactive learning activities into a unified learning environment. This contribution demonstrates the practical feasibility of transforming abstract theoretical concepts into a functional educational application. Moreover, the system serves as an example of how linguistic theory and game-based learning principles can be integrated within a scalable and playable learning platform for Chinese character education.

### *Preliminary Empirical Contribution*

This study provides preliminary empirical evidence regarding the feasibility and educational potential of the proposed approach through a one-group pretest–posttest implementation involving upper secondary school learners. The findings indicate substantial improvements in learners' conceptual

understanding of Chinese characters and positive perceptions of the learning experience provided by the system. These results suggest that theory-driven game mechanics can effectively support structural understanding and learner engagement. Although the study does not aim to establish definitive causal relationships, the findings provide supportive evidence for the educational value of the proposed framework and offer promising directions for future research and development.

## ■ Literature Review

### *Chinese Character Learning and Structural Awareness*

Chinese characters constitute a logographic writing system in which each character conveys meaning, visual form, and, in some cases, phonetic information. This structural complexity presents challenges for learners, particularly those from alphabetic language backgrounds. Effective Chinese character learning therefore requires not only memorization but also the ability to analyze radicals, components, and the relationships among form, sound, and meaning.

A growing body of research has highlighted the importance of structural awareness in Chinese character learning. Learners who can systematically analyze character structures tend to demonstrate deeper understanding, stronger retention, and greater ability to transfer knowledge to unfamiliar characters. For example, Li Dasi (2011) emphasized the role of component analysis in reducing confusion between visually similar characters, while Lu Jun Fang (2022) highlighted the importance of understanding form–sound–meaning relationships. Similarly, Liang Zhong Yu (2023) and Liu Min (2023) argued that instruction emphasizing character structures can strengthen memorization and promote deeper conceptual understanding.

Empirical studies have also supported the effectiveness of structure-based instruction. Salinthip Rattanasangthip and Thidarat Tannirat (2024) found that pictograph-based instruction improved learners' understanding of character origins and increased learning achievement and satisfaction. Sukanya Thonghaeo (2021) reported that single-character structure instruction enhanced memorization and character recognition, while Mintra Paripunna (2024) demonstrated that radical-based instruction improved learners' understanding of semantic relationships and vocabulary retention.

Despite these positive findings, most existing studies have focused on classroom-based approaches, including teacher explanations, visual demonstrations, worksheets, and character analysis activities. In such approaches, structural knowledge is primarily presented as instructional content, providing limited opportunities for learners to actively construct knowledge through interaction and exploration.

From a learning design perspective, structural awareness can serve as a foundation for interactive learning activities that encourage learners to identify, analyze, classify, and relate character components. These processes can be supported through interactive mechanics such as decomposition, pattern recognition, matching, and classification, which align with contemporary perspectives on interactive and

game-based learning emphasizing active participation and meaningful engagement (Kapp, 2012; Lee & Hammer, 2011).

Therefore, while previous studies consistently demonstrate the value of structural awareness in Chinese character learning, relatively little attention has been given to transforming structural knowledge into interactive learning experiences. This gap highlights the need for learning environments that engage learners in actively analyzing and constructing knowledge from Chinese character structures, providing a foundation for the development of interactive game-based learning systems.

### *Liushu Theory and Chinese Character Formation*

Liushu (六书) theory is widely recognized as one of the most influential frameworks for explaining the formation and development of Chinese characters. Originating from Xu Shen's *Shuowen Jiezi* (说文解字), the theory classifies Chinese characters according to the relationships among form, meaning, and pronunciation (Xu Shen, 1963). It remains an important foundation for understanding the structural characteristics of Chinese characters and their development over time.

Traditionally, Liushu consists of six categories: pictographic characters (象形), ideographic characters (指事), compound ideographs (会意), phono-semantic compounds (形声), derivative cognates (转注), and phonetic loan characters (假借). However, contemporary scholars generally agree that the first four categories are directly related to character formation, whereas derivative cognates and phonetic loan characters mainly describe semantic development and character usage rather than character creation itself (Yang Qian, 2022).

In the field of Teaching Chinese as a Foreign Language (TCFL), research primarily focuses on pictographic characters, ideographic characters, compound ideographs, and phono-semantic compounds because these categories provide observable structural relationships that learners can directly analyze and connect with meaning. Previous studies suggest that pictographic characters support visual form–meaning associations, ideographic characters facilitate the understanding of abstract concepts, compound ideographs promote meaning construction through component analysis, and phono-semantic compounds help learners identify relationships between semantic and phonetic components (Lu Jun Fang, 2022; Liang Zhong Yu, 2023). Consequently, these four categories are widely regarded as fundamental to the development of structural awareness in Chinese character learning.

Despite the educational value of Liushu theory, previous studies have largely treated it as instructional content for explaining character origins and structures. Relatively limited attention has been given to its use as a conceptual foundation for designing interactive learning experiences, particularly in digital and game-based learning environments. Yet the structural characteristics of the first four Liushu categories can be transformed into interactive activities such as image–meaning association, symbolic interpretation, component analysis, and semantic–phonetic identification.

Therefore, Liushu theory should be viewed not only as a framework for explaining Chinese character formation but also as a foundation for designing structural learning experiences. For this reason, the present study adopts pictographic characters (象形), ideographic characters (指事), compound ideographs (会意), and phono-semantic compounds (形声) as its primary conceptual framework for developing learning activities that promote structural understanding and Chinese character retention.

### *Existing Chinese Character Learning Applications and Research Gaps*

Many Chinese character learning applications have been developed to support vocabulary acquisition and character memorization through digital learning environments. Existing systems commonly employ flashcards, matching exercises, quizzes, and repetition-based activities to facilitate recognition and recall of Chinese characters (Wang et al., 2024). While these applications have demonstrated positive effects on learner engagement and short-term memorization, most primarily focus on vocabulary learning outcomes rather than fostering an understanding of the structural principles underlying Chinese character formation.

Several studies have incorporated radicals or character components into instructional activities. For example, Mintra Paripunna (2024) utilized radical-based instruction to improve learners' recognition of semantic relationships among characters, while Salinthip Rattanasangthip and Thidarat Tannirat (2024) applied pictograph-based explanations to enhance learners' understanding of character origins. Although these approaches support structural awareness to some extent, the structural knowledge is generally presented as instructional content rather than being embedded within interactive learning processes.

*Table 1.*

Comparison of Existing Chinese Character Learning Approaches and the Present Study

| Study                                                | Focus                  | Approach                     | Key Limitation                                                                     |
|------------------------------------------------------|------------------------|------------------------------|------------------------------------------------------------------------------------|
| Wang et al. (2024)                                   | Vocabulary learning    | Matching game                | Focused on vocabulary memorization rather than character structure                 |
| Mintra Paripunna (2024)                              | Radical instruction    | Radical-based learning       | Emphasized semantic recognition but lacked interactive learning mechanics          |
| Salinthip Rattanasangthip & Thidarat Tannirat (2024) | Pictograph instruction | Visual explanation           | Limited to specific character categories                                           |
| Present Study                                        | Liushu-based learning  | Game mechanics-driven design | Integrates structural understanding, learner interaction, and cognitive processing |

Table 1 summarizes representative Chinese character learning approaches reported in previous studies. Existing approaches have supported Chinese character learning through vocabulary-focused activities, radical-based instruction, and pictograph-based explanations, resulting in improvements in character recognition, semantic understanding, learning achievement, and memorization. However, most approaches focus on specific aspects of character learning and provide limited integration of structural understanding, learner interaction, and cognitive processing.

A common limitation is that structural knowledge is typically presented as instructional content, while game elements are mainly used to enhance motivation rather than support structural learning directly. As a result, learners may improve memorization and recognition without developing transferable structural understanding. These limitations highlight the need for learning environments that integrate Chinese character structure, interactive game mechanics, and meaningful cognitive processing. To address this gap, the present study adopts a game mechanics-driven design approach in which Liushu theory serves as the foundation for both gameplay mechanics and learner interaction. Unlike previous studies that primarily treated Liushu theory as instructional content, the present study positions Liushu as a design foundation for learning mechanics and game mechanics. This distinction represents both a theoretical and design innovation by embedding structural knowledge directly within learner interactions rather than presenting it as explanatory content.

### ***Game-Based Learning and Game Mechanics***

Game-Based Learning (GBL) has been widely recognized as an effective approach for enhancing learner motivation, engagement, and participation through interactive and goal-oriented learning activities. Core elements of GBL, such as challenges, rewards, feedback, and progression systems, can support active learning and increase learner attention (Prensky, 2001; Gee, 2003). Previous studies have also shown that interactive learning environments combined with immediate feedback can improve learner motivation, satisfaction, and learning performance (Hamari et al., 2016; Wang et al., 2024).

However, many existing applications focus mainly on gamification elements rather than the deeper design of game mechanics that directly support cognitive processes. Game mechanics refer to the rules and interaction systems that determine how learners engage with content, solve problems, and receive feedback within a game environment (Kapp, 2012). Mechanics such as classification, matching, sequencing, and feedback loops can be aligned with learning objectives to support meaningful and cognitively structured learning experiences.

Research suggests that well-designed game mechanics can function as cognitive tools that guide learners' thinking and knowledge construction processes. Through activities such as categorization, structural analysis, and interactive problem-solving, learners are encouraged to actively process and organize knowledge rather than passively receive information. This approach aligns with theories of meaningful learning and deep cognitive processing, which emphasize active engagement in learning ( Craik & Lockhart, 1972).

### *Cognitive Learning Principles and Learning Interaction Design*

Cognitive learning theory emphasizes that effective learning occurs through active information processing, meaningful association, and retrieval rather than passive repetition. Concepts such as meaningful learning, deep processing, and retrieval practice suggest that learners retain information more effectively when they actively analyze, connect, and recall knowledge ( Craik & Lockhart, 1972). These principles are especially important in Chinese character learning, where understanding structural relationships supports long-term retention.

In interactive learning environments, cognitive processes can be enhanced through well-designed learning interactions. Activities such as decomposition, classification, and immediate feedback encourage analytical thinking, knowledge organization, and self-correction during learning. Previous studies have shown that interactive learning systems with immediate feedback can improve learner engagement and learning performance (Hamari et al., 2016; Wang et al., 2024). By integrating these cognitive principles with game mechanics, learning environments can support both meaningful learning and sustained learner engagement.

### *Research Gap and Positioning of the Present Study*

The literature reviewed indicates that previous studies have highlighted the importance of structural awareness, Liushu-based instruction, game-based learning, and cognitive learning principles in Chinese character learning. However, these areas have largely been investigated separately, with limited integration into a unified learning design framework. As a result, existing approaches often emphasize structural explanation, instructional strategies, or learner motivation, while relatively little attention has been given to transforming Chinese character structures into interactive learning experiences that support both engagement and knowledge construction.

To address this gap, the present study positions itself at the intersection of Chinese character structure, learning interaction design, and game-based learning. Rather than treating Liushu theory solely as instructional content, the study adopts it as a framework for designing learner interactions and game mechanics based on pictographic (象形), ideographic (指事), compound ideograph (会意), and phono-semantic compound (形声) characters.

The theoretical contribution of this study lies in reconceptualizing Liushu theory as a learning design framework. The design contribution lies in the proposed game mechanics-driven approach, which embeds structural knowledge directly within gameplay interactions. The practical contribution lies in the development and evaluation of the Secret of Hanzi application, which integrates structural awareness, interactive learning, and game-based learning to support Chinese character understanding and retention. Together, these contributions provide a theoretically grounded and practically applicable approach to Chinese character learning.

## ■ Game Mechanics–Driven Design Framework

### *Design Principles*

The design of the proposed interactive learning system is guided by a game mechanics–driven approach, in which game mechanics are positioned as the central mechanism for facilitating learning rather than as supplementary features. The framework integrates linguistic theory, cognitive learning principles, and game-based learning concepts to ensure that gameplay interactions directly support knowledge construction and structural understanding of Chinese characters.

Four key design principles underpin the system. First, structural decomposition emphasizes the analysis of Chinese characters into meaningful components, such as radicals and phonetic elements, enabling learners to understand relationships among form, sound, and meaning. Second, progressive learning supports cognitive development through sequenced gameplay, moving from recognition to higher-order processes such as classification and application. Third, immediate feedback provides real-time responses that allow learners to monitor their understanding, correct errors, and reinforce knowledge. Finally, active engagement is promoted through interactive tasks that require learners to continuously make decisions, solve problems, and interact with content. These principles ensure that game mechanics are tightly aligned with both learning objectives and cognitive processes.

The proposed framework is conceptually aligned with the Learning Mechanics–Game Mechanics model (Arnab et al., 2015), which emphasizes the translation of learning objectives into gameplay interactions. It is also consistent with constructivist learning theory, which views knowledge as actively constructed through learner interaction and problem-solving. Furthermore, the framework reflects principles of the Cognitive Theory of Multimedia Learning by integrating visual representations, immediate feedback, and interactive tasks that support meaningful cognitive processing.

### *Integration of Liushu Theory, Learning Mechanics, and Game Mechanics*

A central feature of the proposed framework is the systematic integration of Liushu theory, cognitive learning processes, learning mechanics, and game mechanics. Drawing upon the Learning Mechanics–Game Mechanics (LM-GM) model (Arnab et al., 2015), the framework assumes that educational game design should begin with intended learning processes rather than game elements alone. Accordingly, Liushu theory serves as the domain-specific knowledge foundation, while cognitive learning principles provide guidance for identifying the learning processes required for Chinese character learning.

Within the proposed framework, each Liushu category is associated with specific cognitive processes and learning mechanics, which are subsequently translated into corresponding game mechanics. Pictographic characters (象形) emphasize visual association and recognition, leading to image–character matching activities. Indicative characters (指事) require learners to interpret abstract symbols and spatial relationships, which are operationalized through

categorization and sorting tasks. Associative compound characters (会意) involve analytical processing and component decomposition, implemented through decomposition puzzles and reconstruction activities. Phono-semantic compound characters (形声) require pattern recognition and classification of semantic and phonetic components, which are translated into classification-based gameplay mechanics.

This mapping ensures that gameplay interactions are directly derived from linguistic structures and cognitive learning processes. Rather than treating Liushu theory as content presented within a game, the framework uses Liushu as a design logic that shapes learning mechanics and gameplay interactions. Consequently, learning objectives are embedded within gameplay itself, allowing learners to construct knowledge through active engagement with game mechanics. The relationship among Liushu theory, cognitive processes, learning mechanics, game mechanics, and intended learning outcomes is summarized in Table 2.

Table 2.

Mapping Liushu Theory, Cognitive Processes, Learning Mechanics, Game Mechanics, and Learning Outcomes

| Liushu Category                      | Structural Characteristics                                                                                  | Cognitive Process                         | Learning Mechanic                      | Game Mechanic                                    | Learning Outcome                                                                           |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------|-------------------------------------------|----------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------------|
| Pictographic Characters (象形)         | Characters visually represent objects found in nature (e.g., 日, 月, 山, 木).                                   | Visual Association                        | Recognition                            | Matching Meaning Game (Image–Character Matching) | Learners connect character forms with meanings and improve character recognition.          |
| Indicative Characters (指事)           | Characters use symbols or markers to represent abstract concepts and spatial relationships (e.g., 上, 下, 本). | Concept Interpretation and Categorization | Classification                         | Basket of Meaning Game (Sorting Activity)        | Learners understand symbolic representations and classify characters according to meaning. |
| Associative Compound Characters (会意) | Characters combine two or more components to                                                                | Analytical Processing                     | Decomposition and Meaning Construction | Associative Compound Character Game (Drag-       | Learners analyze component relationships and infer                                         |

| Liushu Category                         | Structural Characteristics                                                | Cognitive Process                           | Learning Mechanic        | Game Mechanic                                                | Learning Outcome                                                                                              |
|-----------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|--------------------------|--------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
|                                         | create a new meaning (e.g., 休, 明).                                        |                                             |                          | and-Drop Analysis)                                           | character meanings from structural combinations.                                                              |
| Phono-semantic Compound Characters (形声) | Characters contain both semantic and phonetic components (e.g., 河, 湖, 妈). | Pattern Recognition and Structural Analysis | Component Classification | Sound-from-Structure Game (Semantic–Phonetic Classification) | Learners identify semantic and phonetic components and understand the relationship between sound and meaning. |
| All Liushu Categories                   | Knowledge acquired across different character formation principles.       | Retrieval Practice                          | Recall                   | Review and Recall Challenge                                  | Learners strengthen memory retention and reinforce previously learned character knowledge.                    |

To further illustrate the relationship between Liushu categories and game mechanics, specific Chinese character examples were incorporated into the learning activities. For pictographic characters (象形), examples such as 日 (sun) and 月 (moon) are used in image–character matching tasks to strengthen visual associations between character forms and meanings. For indicative characters (指事), characters such as 上 (up) and 下 (down) are employed in classification and interpretation activities that help learners understand abstract symbolic representations. Associative compound characters (会意), including 休 (rest) and 明 (bright), are used in decomposition and meaning-construction tasks, allowing learners to analyze how multiple components combine to create new meanings. For phono-semantic compound characters (形声), examples such as 河 (river), 湖 (lake), and 妈 (mother) are incorporated into semantic–phonetic classification activities, enabling learners to identify semantic and phonetic components and understand the relationship between meaning and pronunciation. These examples demonstrate how the structural principles of Chinese character formation are operationalized through game mechanics to support meaningful learning interactions.

As shown in Table 2, this study focuses on four Liushu categories: pictographic characters (象形字), indicative characters (指事字), associative compound characters (会意字), and phono-semantic compound characters (形声字). Although mutually explanatory characters (转注字) and phonetic loan characters (假借字) are also included in Liushu theory, they are more closely associated with historical language development and semantic change than with direct principles of character formation (Lu Jun Fang, 2022). Therefore, the present framework concentrates on the first four categories, which provide clearer structural characteristics and can be more effectively transformed into learning mechanics and game mechanics for Chinese character learning.

### *Gameplay Flow and Interaction Design*

The gameplay flow is designed to reflect a progression of cognitive complexity, guiding learners from basic understanding to higher-order thinking. The sequence begins with recognition tasks that introduce character forms and meanings, followed by structural analysis activities focusing on component identification and relationships. Learners then engage in classification tasks to organize knowledge and identify structural patterns, before progressing to application and recall tasks that reinforce knowledge transfer and retention.

Interaction design is structured around continuous feedback loops, in which learners perform actions, receive immediate feedback, and adjust their responses accordingly. Game elements such as scoring systems, progression levels, limited attempts, and rewards are integrated to sustain motivation and encourage repeated engagement. Importantly, these elements are not treated as decorative features but as functional components that reinforce learning behaviors and support cognitive processing.

### *Summary of the Design Framework*

The proposed game mechanics-driven design framework demonstrates how linguistic theory, cognitive principles, and game-based learning can be systematically integrated into an interactive learning system. By positioning game mechanics as the core driver of learning interactions, the framework provides a structured approach for transforming abstract knowledge into meaningful gameplay experiences.

The integration of Liushu theory, cognitive processes, and game mechanics not only supports structural understanding in Chinese character learning but also offers a generalizable model for designing educational games in other domains. This framework highlights the importance of aligning game mechanics with learning objectives and provides practical guidance for developing interactive systems that promote both engagement and meaningful learning.

## ■ System Design and Implementation

## System Overview

Based on the proposed game mechanics-driven design framework, the *Secret of Hanzi* system was developed as an interactive game-based learning application for Chinese character learning. The system is designed to support learners in understanding character structures through direct interaction with gameplay mechanics derived from the Liushu theory. The application emphasizes active learning by allowing learners to engage in tasks such as character decomposition, classification, and pattern recognition within a structured game environment. The system is implemented as a digital learning platform accessible via web and mobile environments, enabling flexible use in both classroom and self-directed learning contexts. The overall design focuses on usability, interactivity, and alignment between learning objectives and gameplay interactions, ensuring that learners can navigate the system intuitively while engaging in meaningful learning activities.

## System Architecture

The system architecture consists of three main components: the Learning Module, the Game Engine, and the Feedback System, which work together to support the learning process. The Learning Module manages instructional content based on Liushu theory, including character structures, meanings, and classification categories. It provides structured learning materials that are directly integrated into gameplay activities.

The Game Engine controls the core game mechanics, including puzzle interactions, sorting tasks, matching activities, scoring systems, and progression logic. This component is responsible for delivering interactive gameplay experiences aligned with the design framework. The game was developed using Unity and C# as the primary development environment. The completed application was exported to WebGL format and deployed through the Vercel platform, enabling students to access the game directly through a web browser without installing additional software.

The Feedback System provides real-time responses to learner actions, including correctness indicators, score updates, and guidance, enabling learners to monitor their performance and adjust their understanding. Immediate feedback is presented after each learner action through visual notifications, score changes, and progression indicators. When learners provide incorrect answers, the system allows them to review the correct response and continue the activity, thereby supporting self-correction and reinforcing conceptual understanding.

The game incorporates a progression-based level structure consisting of six learning modules. Each module focuses on different Liushu character categories and gradually increases in cognitive complexity, moving from recognition and matching activities to structural analysis and character classification tasks. This progression is intended to support scaffolded learning and sustained learner engagement.

To support data collection and learning analytics, Google Apps Script and Google Sheets were integrated into the system to automatically record

students' gameplay scores and learning progress. Prior to classroom implementation, the system was tested by the research team to verify gameplay functionality, scoring accuracy, feedback delivery, and data recording processes.

### Game Mechanics Implementation

The implementation of game mechanics in the system directly reflects the mapping presented in Table 1. Each mechanic is designed to operationalize a specific learning process and align with both cognitive principles and Liushu theory. The decomposition puzzle mechanic enables learners to break down Chinese characters into components and reconstruct them, supporting analytical processing and structural understanding. The sorting mechanic requires learners to classify characters based on structural features or Liushu categories, promoting knowledge organization and pattern recognition. The matching mechanic is used to connect images, meanings, and character forms, supporting visual association and recognition, particularly for pictographic characters. The recall challenge mechanic provides tasks that require learners to retrieve previously learned information, reinforcing memory consolidation and long-term retention. These mechanics are integrated into gameplay in a way that ensures learning occurs through interaction. Rather than presenting content separately, the system embeds learning tasks within the mechanics themselves, allowing learners to construct knowledge actively.

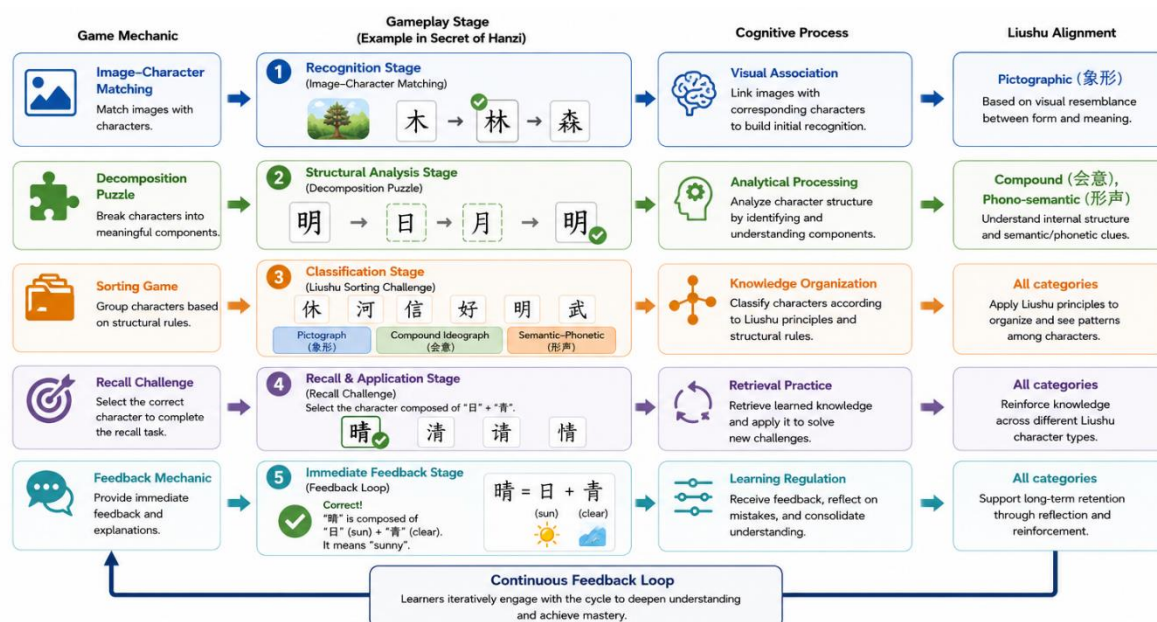


Figure 1. Gameplay Flow Derived from the Game Mechanics-driven Design Framework

### User Interface and Interaction Design

The user interface (UI) and user experience (UX) design of the system are developed to support ease of use, clarity, and engagement for upper secondary school learners. The interface incorporates visual elements such as icons, illustrations, and color-coded components to facilitate intuitive interaction and

enhance learner motivation. Interaction design is structured around a continuous action–feedback loop. Learners perform actions such as selecting answers, dragging components, or sorting characters, and immediately receive feedback from the system. This feedback is presented through visual cues, score updates, and progression indicators, enabling learners to recognize their performance and adjust their responses in real time. In addition, the system incorporates gamification elements such as levels, rewards, and progression indicators to maintain engagement. These elements are designed not only to motivate learners but also to reinforce learning behaviors and encourage repeated interaction with the content. As shown in Figure 2, the main interface emphasizes clear navigation and visual cues to support ease of use for upper secondary learners.



Figure 2. Main User Interface of the Secret of Hanzi System

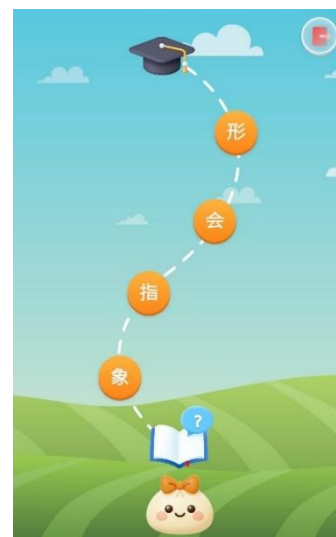


Figure 3. Level Selection And Progression Interface

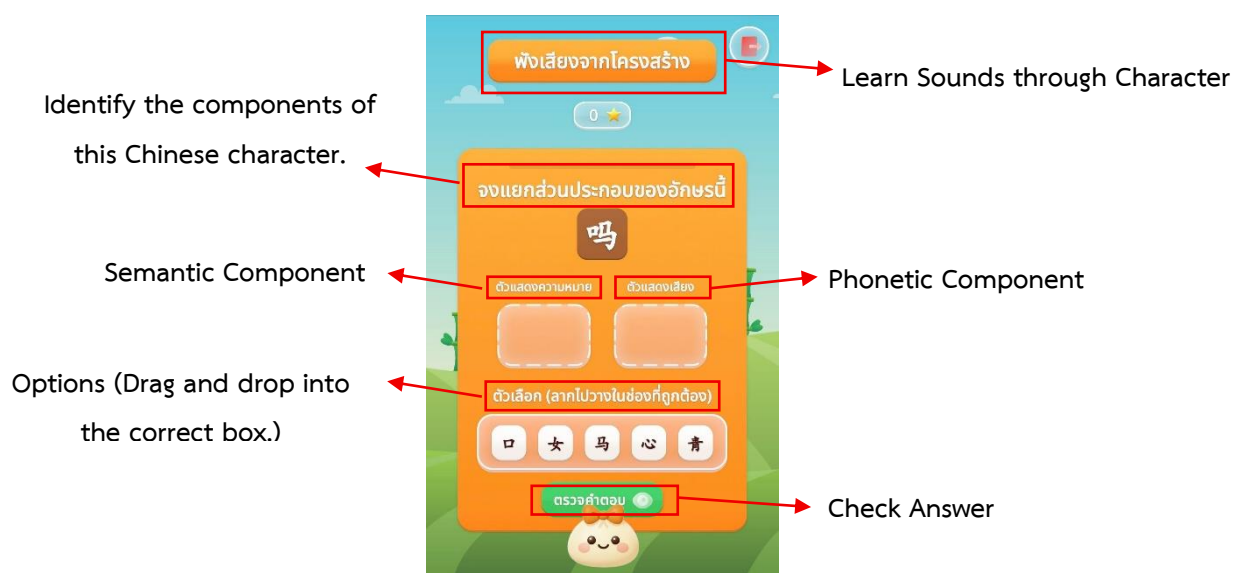


Figure 4. Gameplay and Feedback Screen for Decomposition and Classification Tasks

Figures 3 and 4 present key gameplay screens, including level selection and in-game interactions such as drag-and-drop decomposition, classification, and immediate feedback indicators. These interfaces make the Liushu-based mechanics visible to learners and connect abstract character structures to concrete actions.

### ***Implementation Tools and Development Process***

The development of the *Secret of Hanzi* system was carried out using digital tools and frameworks suitable for interactive learning applications. The system was designed to support cross-platform accessibility, allowing it to be deployed on both web-based and mobile environments. The development process followed an iterative approach, in which the system was continuously refined based on design principles and usability considerations. The implementation focused on integrating content, interaction, and feedback mechanisms into a cohesive system that reflects the game mechanics-driven framework. Particular attention was given to ensuring that each gameplay component aligns with the intended learning objectives and supports meaningful interaction.

### ***Summary of System Implementation***

The *Secret of Hanzi* system demonstrates how the proposed game mechanics-driven design framework can be translated into a functional interactive learning application. By integrating Liushu-based content with carefully designed game mechanics, the system provides a structured and engaging environment for Chinese character learning. The implementation highlights the practical feasibility of aligning linguistic theory, cognitive learning principles, and game-based interaction within a single system. This approach not only supports structural understanding and learner engagement but also offers a scalable model for developing interactive educational systems in other learning domains.

## **■ Methodology**

### ***Research Design***

This study adopts a design and development research approach, focusing on the creation and implementation of a game mechanics-driven interactive learning system for Chinese character learning. The primary objective is to examine how linguistic theory and game mechanics can be systematically integrated into an operational learning environment.

To support the evaluation of the proposed system, a pre-experimental one-group pretest–posttest design was employed. This design was used to assess the feasibility and educational potential of the developed system, rather than to establish strong causal claims. The evaluation focuses on examining

learning outcomes and learner experiences as supporting evidence for the effectiveness of the design framework.

### ***Participants***

The participants consisted of upper secondary school students studying Chinese as a foreign language in Chiang Mai, Thailand. A total of 60 students participated in the study, representing a typical classroom context in which the system is intended to be applied. The participants had similar levels of prior exposure to Chinese character learning, ensuring a relatively consistent baseline for evaluating the system.

### ***Research Instruments***

The study employed three main instruments for data collection. First, a Conceptual Understanding Test of Chinese Characters was used to measure students' understanding of character structures, memorization ability, and application skills. The test was administered both before and after the intervention to examine changes in learning performance. Second, a Learner Satisfaction Questionnaire was used to assess students' perceptions of the system, including engagement, perceived usefulness, and support for structural understanding. The questionnaire provides insights into the user experience and interaction quality of the system. Third, the Secret of Hanzi Interactive Learning System itself functioned as the primary intervention. The system integrates multiple game mechanics, including decomposition puzzles, classification tasks, matching activities, and recall challenges, which are aligned with Liushu theory and cognitive learning principles.

### ***Conceptual Understanding Test of Chinese Characters***

A Conceptual Understanding Test of Chinese Characters was developed based on the learning objectives of the study and the structural categories of Liushu theory. The test consisted of 50 items covering three dimensions: structural understanding (20 items), character memorization (25 items), and application of structural knowledge (5 items). The test was administered before and after the intervention to examine changes in students' learning performance. To establish content validity, the test items were reviewed by three experts in Chinese language teaching and educational technology. The Item–Objective Congruence (IOC) values ranged from 0.67 to 1.00, indicating acceptable content validity for all items.

### ***Learner Satisfaction Questionnaires***

A learner satisfaction questionnaire was employed to evaluate students' perceptions of learning through the Secret of Hanzi system after the intervention. The questionnaire assessed six aspects of the learning experience, including ease of interaction,

perceived learning value, support for structural understanding, engagement level, intention for continued use, and overall user experience. The questionnaire was reviewed by three experts, and the average IOC value was 0.78, indicating acceptable content validity.

The reliability of the learner satisfaction questionnaire was assessed using Cronbach's alpha coefficient. Based on responses from 60 participants, the questionnaire achieved a Cronbach's alpha of .931, indicating excellent internal consistency and satisfactory reliability for research purposes.

### ***Secret of Hanzi Interactive Learning System***

The Secret of Hanzi Interactive Learning System served as the primary intervention in this study. The system integrates multiple game mechanics, including decomposition, classification, matching, and review activities, which are aligned with Liushu theory and cognitive learning principles. In addition, the lesson plans and system design were evaluated by experts for appropriateness prior to classroom implementation.

### ***Procedure***

The study was conducted in three phases: pre-intervention, intervention, and post-intervention. During the pre-intervention phase, participants completed a pre-test measuring their conceptual understanding of Chinese character structures and a baseline satisfaction questionnaire.

The intervention was implemented over four weeks, with two instructional periods per week, resulting in a total of eight class periods. Each instructional period lasted 50 minutes. The study was conducted with 60 Grade 10 students during regular Chinese language classes at a secondary school in Chiang Mai, Thailand.

The learning activities were organized into four instructional units covering Chinese character formation, pictographic and associative compound characters, ideographic and phono-semantic compound characters, and review activities. In each lesson, the teacher first introduced the learning objectives and provided explanations of the structural principles underlying each Chinese character category. Classroom instruction included examples, discussions, and guided analysis to help students understand the relationships among character forms, meanings, and structures.

Following the instructional phase, students completed practice activities and reviewed the content through the Secret of Hanzi application. The application functioned as a supplementary learning tool that reinforced classroom instruction through interactive game-based activities, including matching, classification, structural analysis, interpretation, and review tasks based on different Liushu character categories. Through these activities, students were encouraged to apply the knowledge learned in class, analyze character structures independently, and actively construct their understanding through interaction and immediate feedback.

In the post-intervention phase, participants completed the same conceptual understanding test and a learner satisfaction questionnaire. The collected data were used to examine changes in learning performance and learner perceptions following the implementation of the system.

### Data Analysis

The collected data were analyzed using descriptive and inferential statistical methods. Descriptive statistics, including mean and standard deviation, were used to summarize learning performance and learner perceptions. To examine changes in conceptual understanding before and after the intervention, inferential analysis was conducted using appropriate statistical techniques. In addition, qualitative interpretation of learner responses was used to complement the quantitative findings, providing a broader understanding of learner engagement and interaction with the system. The analysis focuses on identifying patterns that support the feasibility and educational potential of the game mechanics-driven design approach.

## Results

### Results of Conceptual Pre-test and Post-test

To examine the feasibility and educational promise of the Secret of Hanzi system as an instantiation of the proposed game mechanics-driven design framework, students' conceptual understanding of Chinese characters was assessed before and after engaging with the system. As presented in Table 3, a paired-samples t-test revealed a statistically significant improvement in conceptual understanding following the intervention,  $t(59) = 25.01$ ,  $p < .001$ . Students achieved significantly higher post-test scores ( $M = 70.75$ ,  $SD = 14.28$ ) than pre-test scores ( $M = 20.33$ ,  $SD = 9.08$ ), with a mean difference of 50.42, 95% CI [46.38, 54.45]. Furthermore, the intervention resulted in a very large effect size (Cohen's  $d = 3.23$ ), indicating substantial educational impact.

Table 3.

Pre- and post-test scores as feasibility evidence for the Secret of Hanzi system

| Test       | n  | Mean<br>(M) | SD    | Mean<br>Difference | 95% CI        | t     | df | p      | Cohen's d |
|------------|----|-------------|-------|--------------------|---------------|-------|----|--------|-----------|
| Pre-test   | 60 | 20.33       | 9.08  | —                  |               | —     | —  | —      |           |
| Post-test  | 60 | 70.75       | 14.28 | —                  |               | —     | —  | —      |           |
| Post – Pre | 60 | —           | —     | 50.42              | [46.38,54.45] | 25.01 | 59 | < .001 | 3.23      |

The magnitude of the mean difference (50.42), together with the narrow 95% confidence interval [46.38, 54.45], further highlights the practical significance of the intervention, suggesting that the learning

improvement was not only statistically significant but also educationally meaningful. The very large effect size (Cohen's  $d = 3.23$ ) indicates that the observed gains were substantial and consistent across participants. In the context of this design and development study, these results serve as preliminary empirical evidence that the implemented mechanics—particularly decomposition, classification, and progressive challenges—can effectively support analytical processing and structural understanding of Chinese characters.

Moreover, the observed pattern of improvement appears to be consistent with the intended learning processes embedded in the system. Learning activities involving decomposition and classification may have contributed to learners' ability to identify structural components and organize character knowledge more systematically, while recall-oriented activities likely supported the reinforcement of previously encountered characters. Although the present study was not designed to isolate the effects of individual game mechanics, the alignment between the observed learning gains and the pedagogical functions of the implemented mechanics provides further feasibility evidence for the proposed design framework. These findings suggest that the Liushu-informed game mechanics can be successfully operationalized within a game-based learning environment and may support the development of conceptual understanding of Chinese characters.

### *Results of the Questionnaire*

To further evaluate the feasibility and practical usability of the Secret of Hanzi system, students' perceptions of their learning experience were gathered using a user experience questionnaire. Table 4 summarizes the mean scores and standard deviations for each evaluation aspect.

*Table 4.*

User experience ratings as usability and acceptance evidence for the system

| Evaluation Aspect                    | n  | Mean Score | SD   |
|--------------------------------------|----|------------|------|
| Ease of Interaction                  | 60 | 4.45       | 0.69 |
| Perceived Learning Value             | 60 | 4.52       | 0.63 |
| Support for Structural Understanding | 60 | 4.48       | 0.66 |
| Engagement Level                     | 60 | 4.56       | 0.58 |
| Intention for Continued Use          | 60 | 4.60       | 0.55 |
| Overall User Experience              | 60 | 4.52       | 0.62 |

As shown in Table 4, students reported consistently high ratings across all evaluated aspects of the Secret of Hanzi system, suggesting a positive user experience and a generally high level of practical acceptability in the classroom context. Notably, the highest scores were observed in intention for continued use ( $M = 4.60$ ,  $SD = 0.55$ ) and engagement level ( $M = 4.56$ ,  $SD = 0.58$ ), suggesting that the system is not only engaging in the short term but also associated with a strong willingness among learners to continue using the system. The relatively low standard deviations across these dimensions indicate a high degree of

consensus among participants, reinforcing the interpretation that the system is broadly well received rather than appealing only to a small subgroup of learners.

High mean scores in perceived learning value ( $M = 4.52$ ,  $SD = 0.63$ ) and support for structural understanding ( $M = 4.48$ ,  $SD = 0.66$ ) further suggest that learners regarded the system as both enjoyable and educationally meaningful. In the context of this design and development study, these evaluations provide usability- and value-oriented feasibility evidence that the Liushu-informed game mechanics—such as decomposition, classification, and immediate feedback—can be integrated into a learning environment that learners perceive as supportive for understanding character structures. This balance between engagement and perceived learning benefit is critical for the long-term viability of game-based learning systems in authentic educational settings.

Although ease of interaction ( $M = 4.45$ ,  $SD = 0.69$ ) received slightly lower ratings compared with other aspects, the score still falls within a high range, indicating that the interface is generally accessible to upper secondary students. The somewhat higher variability in this dimension may reflect differences in students' familiarity with digital learning environments, pointing to potential areas for refinement in interface design and onboarding support. Overall, the questionnaire findings complement the learning outcome results by showing that the proposed game mechanics-driven design is not only pedagogically promising but also usable and acceptable for classroom implementation, while warranting further refinement and evaluation in larger-scale educational settings.

## ■ Discussion and Conclusion

The findings of this study should be interpreted primarily as feasibility evidence for the proposed game mechanics-driven design framework for Chinese character learning. Within a design and development research context, the substantial improvements in conceptual understanding and the consistently positive user experience ratings indicate that the Secret of Hanzi system can be successfully implemented in an authentic classroom setting and can produce promising learning and engagement outcomes. Rather than aiming to establish strong causal claims or to compare the system with alternative instructional approaches, the study focuses on demonstrating that theory-informed game mechanics can be operationalized into a functional and pedagogically meaningful game-based learning environment. These findings provide converging evidence that the mechanics-driven design can function as a viable instructional approach.

The results from the conceptual pre-test and post-test suggest that mechanics such as decomposition puzzles, classification tasks, and progressive challenges can effectively support analytical processing and structural understanding of Chinese characters. The large mean gain from pre-test to post-test and the shift from a uniformly low baseline toward markedly higher post-test performance provide preliminary empirical support for the central design assumption of this work: that aligning game mechanics with the structural characteristics of Chinese characters enables learners to move beyond surface-level memorization toward deeper conceptual understanding.

In particular, the observed patterns of improvement correspond closely with the targeted cognitive processes encoded in the design framework, indicating that the mechanics functioned as intended in guiding learners' analysis, organization, and retrieval of character knowledge.

The questionnaire findings complement these learning outcomes by providing usability- and acceptance-oriented feasibility evidence. High ratings in engagement level and intention for continued use indicate that the system is capable of sustaining learner motivation, an essential condition for the practical adoption of game-based learning tools in real classrooms. At the same time, strong evaluations in perceived learning value and support for structural understanding suggest that learners did not experience the system merely as entertainment but recognized it as a meaningful learning tool. This balance between enjoyment and perceived educational benefit is critical for the long-term viability of educational games, reinforcing the argument that game mechanics should be designed as cognitive tools rather than decorative add-ons. The slightly lower yet still high scores in ease of interaction point to areas where interface design and onboarding could be refined, offering concrete directions for iterative improvement in future design cycles.

Taken together, these findings highlight the importance of positioning game mechanics as a central component in the design of game-based learning systems. By systematically mapping Liushu (六书) categories to specific game mechanics and cognitive processes, the proposed framework demonstrates how linguistic theory can provide a rigorous foundation for gameplay design. The Secret of Hanzi system serves as a proof-of-concept implementation that makes this mapping tangible, illustrating how abstract constructs of Chinese character formation can be transformed into concrete interaction patterns such as decomposition, classification, and recall challenges. In doing so, the study contributes a reusable design logic that other developers and educators can adapt when creating theory-informed educational games in related domains.

At the same time, several limitations should be acknowledged when interpreting the results. First, this study employed a pre-experimental one-group pretest–posttest design without a control group, comparison group, or random assignment. Therefore, the findings should be interpreted cautiously. Although the results provide promising evidence regarding the feasibility and educational potential of the Secret of Hanzi system, they do not allow strong causal conclusions that the observed learning gains were solely attributable to the application or the proposed game mechanics–driven design framework. It is difficult to rule out the influence of other factors, including maturation effects, testing effects, teacher influence, and classroom environmental factors, which may also have contributed to the observed improvements.

Second, the study was conducted with a single group of upper secondary students in one educational context, which may limit the generalizability of the findings. Furthermore, the evaluation focused primarily on short-term conceptual understanding and self-reported user experience, leaving questions about long-term retention, transfer of learning, and sustained learner engagement for future investigation.

Future research can build on this work in several directions. First, future studies should employ more rigorous quasi-experimental or randomized controlled designs with control or comparison groups to

provide stronger causal evidence regarding the effectiveness of the proposed framework. Such designs would help reduce potential threats to internal validity and enhance the credibility of the findings. Second, longitudinal studies could explore how sustained use of Liushu-informed game mechanics influences long-term retention, strategy development, and learner autonomy in Chinese character learning. In addition, future research should investigate the durability of learning outcomes, knowledge transfer, and sustained learner engagement over extended periods of time. Third, the design framework itself could be extended and adapted to other linguistic domains or writing systems, examining how theory-to-mechanics mappings might operate in different content areas. Finally, iterative design cycles involving teachers and learners as co-designers could further refine the usability and contextual fit of the system, enhancing its scalability and integration into diverse educational settings.

In conclusion, this study presents a game mechanics-driven approach to the design and development of a Liushu-based interactive learning system for Chinese character learning. By integrating linguistic theory, cognitive learning principles, and carefully designed game mechanics, the proposed framework offers a structured method for transforming abstract theoretical constructs into engaging and meaningful gameplay experiences. The preliminary learning and user experience results provide converging feasibility evidence that the Secret of Hanzi system can support structural understanding and learner engagement in authentic classroom contexts. While further research is needed to validate and extend these findings, the work contributes a design-oriented perspective that bridges the gap between linguistic theory, game mechanics design, and interactive learning systems, and it offers a practical foundation for future developments in theory-driven game-based language education.

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