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Original Paper

Enhancing Elementary Chinese Character Instruction through Digital Technologies and Artificial Intelligence: Practical Pathways and Strategies

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Abstract

Addressing structural challenges in elementary-level Chinese character instruction within International Chinese Language Education, this study explores practical pathways and strategies for transforming pedagogy through digital technologies and artificial intelligence (AI). It proposes an integrated four-dimensional instructional framework encompassing recognition, reading, writing, and application. In the recognition phase, technologies such as dynamic etymology and augmented reality (AR) are employed to enhance visualization. The reading phase utilizes intelligent speech assessment for precise feedback. The writing phase incorporates stroke order tracking and AI-powered assessment to address specific learning difficulties. In the application phase, adaptive exercises and contextualized scenarios are used to promote the internalization of Chinese character knowledge. Implementation strategies include redefining the teacher's role, adopting blended learning models, and introducing data-informed interventions. The ultimate objective is to shift Chinese character pedagogy from an experience-driven model to a data-driven paradigm of personalized learning, thus fostering a human-computer collaborative teaching ecosystem.

Keywords

Digital and Intelligent Technologies, International Chinese Language Education, Chinese Character Pedagogy

1. Introduction

Chinese characters constitute the primary challenge in elementary-level Chinese language acquisition, particularly for learners from non-logographic language backgrounds. The substantial differences between Chinese characters and alphabetic writing systems—including their abstract visual features, complex orthographic structure, and the disjunction between form, sound, and meaning—pose major cognitive barriers for learners (Guo, T., 2019, pp. 19-24). Without effective pedagogical interventions, these challenges can persist, significantly undermining students' motivation and learning outcomes (Li, J. L., 2003, pp. 110-111).

Amid the accelerating digital transformation of education worldwide—driven in part by China's "Education Informatization 2.0 Action Plan" (a national policy promoting advanced educational technologies) (Ministry of Education of the People's Republic of China, 2018) and the establishment of the National Smart Education Platform—the integration of digital technologies and AI into language instruction has become a prevailing trend. Consequently, addressing the enduring challenges in elementary Chinese character teaching through innovative technological solutions has become both a pedagogical imperative and a necessary adaptation to global educational developments.

Although existing studies have explored the role of digital and intelligent technologies in Chinese character pedagogy, most concentrate on individual technological interventions or the enhancement of isolated teaching components. A comprehensive framework that harnesses advanced technologies—such as big data analytics, artificial intelligence, and learning analytics—to holistically transform all phases of character instruction remains underdeveloped. Specifically, there is a notable gap in the integration of all four core dimensions—recognition, reading, writing, and application—into a synergistic, technology-empowered instructional model (Cui, X. L., 2024, pp. 11-19; Tian, H., 2024, pp. 85-92). This study addresses this gap by investigating practical pathways and strategies for digitally and intelligently empowered instruction of elementary Chinese characters, aiming to develop a framework with both theoretical grounding and practical applicability to advance the field.

2. The Current State of Elementary Chinese Character Instruction and the Opportunities for Digital and Intelligent Transformation

Elementary-level instruction of Chinese characters has long faced significant structural challenges, primarily reflected in four aspects. First, at the level of orthographic cognition, the abstract symbolic system and complex spatial structures of Chinese characters impose a heavy memory burden on non-native learners. Empirical studies have shown that errors made by learners from non-Chinese-script backgrounds during writing are highly concentrated, with stroke placement errors being particularly prominent. This directly highlights a weakness in their perception of both the structural components of characters and their overall configuration (Guo, T., 2019, pp. 19-24). Second, regarding writing skills, although the strategy of "recognize before writing, recognize more and write

less" (a pedagogical approach) has been proven effective (Feng, L. Y., 2010, pp. 92-96), teachers in traditional classrooms—even with the aid of digital tools—struggle to provide immediate and precise feedback on each student's stroke order and formation. This often leads to the solidification of erroneous writing habits, making it difficult for learners to develop a correct logical understanding of Chinese character composition. Third, establishing associations between phonetic forms and meanings remains challenging. The phenomena of "recognizing pinyin but not characters" and "knowing words but not their constituent characters" are widespread. Influenced by negative transfer from their native languages, learners tend to treat pinyin as Chinese orthographic symbols and memorize vocabulary as holistic sound modules, yet are unable to effectively identify, comprehend, or utilize individual characters within words. This seriously constrains their language development at a deeper level (Liu, J. T., 2010, p. 118). Fourth, the learning process is often deprived of interest and a sense of achievement: repetitive mechanical writing drills and tedious rote memorization frequently lead to frustration and learning anxiety among students (Li, J. L., 2003, pp. 110-111). These issues underscore the limitations of traditional teaching approaches in terms of resources, individualized support, and timely feedback.

"Digital and intelligent technologies" refer to a composite of next-generation intelligent tools, including artificial intelligence (AI), big data, learning analytics (LA), augmented reality (AR), virtual reality (VR), and others. The rapid advancement of such technologies—known for their core strengths in visualization, interactivity, personalization, and data-driven processes—offers a historic opportunity to overcome the longstanding dilemmas of Chinese character instruction. The empowerment enabled by digital and intelligent technologies is not a matter of technology completely replacing the teacher's role. Rather, it is realized through data-driven diagnostics, adaptive learning recommendations, and instant feedback, creating a closed loop of teaching and learning that enhances both teachers' instructional design capabilities and students' cognitive efficiency. This exploration constitutes not merely an update of teaching tools, but a profound restructuring of instructional paradigms. At its core are two major transformations: first, a shift from "experience-driven" to "data-driven" pedagogy. Traditional instruction relies heavily on teachers' personal judgment of learners' progress, while digital and intelligent platforms accurately capture and analyze each learner's behavioral data—from the sequence of stroke execution to the reaction time for distinguishing visually similar characters—objectifying and quantifying previously implicit learning processes, and providing an objective foundation for targeted interventions. Second, there is a transition from "uniform instruction" to "personalized instruction." Supported by learning analytics, systems can generate individualized learner profiles and personalized knowledge graphs, and can intelligently deliver exercises aligned with learners' cognitive level, learning progression, and memory retention patterns, thereby achieving truly personalized teaching. This direction demonstrates that the application of technology in Chinese character instruction is evolving from a "compensatory" model—designed to remedy weaknesses in traditional instruction—toward an "empowerment" model that fundamentally enhances learning

efficiency and experience for each individual. It not only concerns the use of technological tools, but also entails a systemic reconfiguration of educational objectives, processes, and teacher-student roles. This reconfiguration lays a practical foundation for constructing an integrated, technology-empowered pathway that synergizes character recognition, reading, writing, and application.

3. Practical Pathways for Empowering Elementary Chinese Character Instruction with Digital and Intelligent Technologies

In response to the core challenges across the four key phases of elementary Chinese character teaching—recognition, reading, writing, and application—this study proposes a learner-centered, data-driven four-dimensional empowerment framework. The goal is to transcend the isolated application of traditional digital tools, and, by integrating digital and intelligent technologies, provide a systematic solution for overcoming the structural difficulties inherent in Chinese character acquisition.

3.1 Recognition: Intelligent Character Analysis and Visualized Presentation

To address the "orthographic memorization difficulty" stemming from the abstract nature and structural complexity of Chinese characters, a primary empowerment pathway of digital and intelligent technologies is the transformation of static, two-dimensional characters into dynamic, multidimensional, and logically organized visual information.

First, the dynamic etymological demonstration pathway leverages animation technology to vividly reproduce the evolutionary processes of Chinese characters, shifting mechanical memorization toward logical understanding. For instance, AI-generated animations can illustrate how "明 (míng)"—composed of "日 (sun)" and "月 (moon)"—signifies brightness derived from the union of both celestial bodies, or how "休(xiū)" represents a person (人) resting alongside a tree (木). This approach situates characters within their cultural and historical contexts, enabling learners not only to recognize the surface forms but also to understand their underlying rationale (Wei, S. Y., 2024, pp. 75-77).

Second, the component decomposition pathway utilizes artificial intelligence technologies in image recognition and natural language processing to automatically and hierarchically break down compound characters, highlighting functional components such as semantic and phonetic radicals, as well as stroke structures. This serves as the basis for constructing a visualized "Chinese character family tree." For example, the system groups "河 (river)", "湖 (lake)", and "海 (sea)" under the family characterized by the "氵" water radical, and "请(to invite)", "情 (feeling)", and "清 (clear)" under families marked by the "青" phonetic component. This enables learners to establish a systematic network of word-formation knowledge, facilitating a cognitive leap from memorizing individual characters to mastering the rules of character construction (Wang, Y. L., 2019, pp. 188-189).

Lastly, the AR-immersive recognition pathway employs augmented reality technology to seamlessly link Chinese characters with the real world. Learners can use mobile devices or tablets to scan real-world objects—such as a desk, a computer, or an apple—prompting immediate display of the corresponding Chinese characters (“桌子”, “电脑”, “苹果”) on the screen, accompanied by standard pronunciation and bilingual explanations. Meta-analytic research has confirmed that AR technology can significantly enhance learning outcomes (Jiakai, Z., Gege, L., Qinglin, H. et al., 2022, p. 9725). In elementary Chinese character education, this pathway situates the abstract task of character learning within concrete, immediate contexts, greatly strengthening the associations among the sound, form, and meaning of characters. Not only does this mitigate the effects of negative transfer from the learner’s native language, but it also shifts learners from passive recognition to active discovery.

3.2 Reading: Precise Speech Recognition and Mimicry Training Pathway

To address the challenges of mastering the Chinese pinyin system, especially tones, digital and intelligent technologies deliver solutions that go far beyond traditional audio repetition methods in terms of precision and personalization.

At the core of this pathway is intelligent speech assessment technology. Leveraging deep learning-based speech recognition algorithms, the system provides real-time analysis of learners’ pronunciation during recitation, scoring their output across multiple dimensions such as initials, finals, and tones. More importantly, the system offers visualized diagnostic feedback, such as tonal graphs that directly display the learner’s tone contours against standard pronunciation, or pinpoint common phonetic confusions (e.g., distinctions between “z”/“zh”, “d”/“t”). Intelligent speech technologies, such as those represented by iFLYTEK, can now deliver precise pronunciation evaluation and diagnostics for second-language learners. This immediate, objective feedback mechanism effectively compensates for the traditional limitation where teachers are unable to correct students’ tones or articulation on an individual and frequent basis. In addition, multimodal pronunciation tools support autonomous learning by enabling students to hear pronunciations upon tapping a character while also seeing mouth-shape animations or tongue placement diagrams, thereby converting implicit articulatory knowledge into explicit visual and kinesthetic guidance.

3.3 Writing: Interactive Practice and Instant Feedback Pathway

To tackle the persistent challenge of “stroke order difficulty” and to alleviate the monotony of traditional writing drills, the empowerment pathways of digital and intelligent technologies focus on process tracking, intelligent evaluation, and motivation enhancement.

The foundational pathway, dynamic stroke order generation and real-time tracking, employs animation to display the standard sequence of strokes. Learners follow prompts to write on touchscreen devices, where the system tracks their brushwork in real time; should errors in stroke order or direction occur, the system immediately pauses the process and delivers corrective cues. In this way, incorrect habits can be addressed at their inception (Tian, H., 2024, pp. 85-92), supporting the gradual development of

logical reasoning for character composition.

The intelligent handwriting assessment system enables deep analysis of the writing output. Distinct from basic right-or-wrong judgments, the system—driven by computer vision—assesses handwriting across multiple metrics: stroke accuracy (such as length and angle), spatial structure (component proportions and positional relationships), and overall aesthetics. In addition to overall scores, the system provides individualized suggestions for improvement, such as recommending that the left "木" radical in a side-by-side character structure should be narrower, while it ought to be flatter in stacked structures—realizing the kind of fine-grained guidance that, in the past, was possible only through one-on-one tutoring.

Research has shown that gamification can significantly increase engagement and motivation (Kapp, K. M., 2012), transforming repetitive drills into compelling challenges. To address the tedium of practice, gamification mechanisms are embedded within writing exercises. For example, in "Character Parkour", learners must correctly write characters to overcome obstacles, while "component assembly" games require putting together radicals to form valid characters. Points, badges, and leaderboards combine extrinsic motivation (task completion incentives) with intrinsic motivation (enjoyment and a sense of achievement), turning otherwise mechanical practice into challenging tasks and thus significantly enhancing learners' initiative and immersive experience.

3.4 Application: Contextualized Application and Personalized Reinforcement Pathways

"Application" represents the ultimate goal of Chinese character learning. To address persistent challenges such as weak connections among sound, meaning, and form, limited transfer of learned characters to communicative use, and the rapid rate of forgetting, contextualized application and intelligent reinforcement—enabled by digital and intelligent technologies—have become essential strategies for integrating Chinese characters into communicative practice.

First, the adaptive exercise delivery pathway lies at the heart of personalized reinforcement. Leveraging Learning Analytics (LA), the adaptive exercise system constructs an individualized error database and knowledge graph for each learner. When the error rate on a particular knowledge point exceeds a preset threshold, the system automatically generates and delivers targeted micro-lessons and discrimination drills. This data-driven approach to remedying knowledge gaps ensures exercise specificity and efficiency.

Second, the Spaced Repetition System (SRS), based on Ebbinghaus's forgetting curve, is recognized as one of the most effective strategies for combating memory decay. Intelligent learning platforms can calculate the optimal review intervals for each learner based on their study content and progress, automatically issuing review tasks at critical moments just before forgetting is likely to occur. This algorithm-driven approach is more scientific, efficient, and personalized than fixed, one-size-fits-all review schedules, and it supports more sustainable learning outcomes.

Finally, gamified and scenario-based applications utilizing technologies such as AR and VR integrate Chinese character usage into virtual communicative tasks. For example, in a virtual restaurant, learners must recognize menu items and input dish names in Chinese to complete ordering tasks; in a virtual city, they find destinations by interpreting Chinese characters on street signs and shop fronts. Such learning processes not only consolidate students' mastery of character sound, form, and meaning, but, more importantly, situate character learning within meaningful communicative contexts. This enables learners to "learn through use and use through play", effectively addressing the lack of linkage between learning and application as well as compensating for the absence of authentic communicative contexts in traditional instruction to some extent.

4. Implementation Strategies for Digitally and Intelligently Empowered Chinese Character Instruction

The effective empowerment of Chinese character pedagogy by digital and intelligent technologies relies on the adoption of systematic teaching strategies. To ensure the practical implementation of the four-dimensional pathways of "recognition, reading, writing, and application", it is essential to reshape the relationship between teaching and learning and to construct a new paradigm of human-computer collaborative instruction.

4.1 Strategy for Reconstructing the Teacher's Role

The teacher's role is shifting from that of a traditional knowledge transmitter to a designer of learning experiences, an organizer of instructional activities, and an emotional motivator. Unlike conventional models, technology platforms now assume a substantial share of repetitive and knowledge-based instructional tasks, such as stroke order demonstration, pronunciation correction, and grading of basic exercises. Teachers, on the other hand, are expected to design tiered learning tasks based on learning analytics data (for example, assigning differentiated character recognition games to students at different proficiency levels), organize integrated online and offline group activities (such as AR-based Chinese character treasure hunts), monitor student progress using learning analytics data provided by the platform, offer timely feedback, and provide emotional support and psychological guidance to students facing difficulties or anxiety (Wei, S. Y., 2024, pp. 75-77). This role transformation demands that teachers possess a high level of digital literacy; they should act as leaders in human-computer collaboration and as designers of the entire instructional process, rather than as objects to be replaced by technology. The focus is on cultivating students' Chinese character learning strategies and capacity for autonomous learning within a digitally empowered environment.

4.2 Strategy for Constructing a Blended Learning Model

A blended instructional model that deeply integrates "online + offline" learning through digital empowerment should not be viewed as a simple aggregation of online activities and face-to-face classroom teaching, but rather as a synergistic approach with redesigned processes. In the online phase, students can engage in self-directed learning using the platform—for example, watching character

etymology animations, using AI-based speech assessment for pronunciation and character recognition practice, and completing adaptive writing exercises—thereby achieving personalized input and consolidation of knowledge. Offline classroom sessions, in turn, focus on knowledge internalization and practical application: teachers can organize collaborative group projects based on real-world scenarios (such as designing a Chinese menu), or facilitate cultural experience activities such as calligraphy or seal carving, deepening understanding of Chinese character culture. This "online self-learning, offline intensive practice" model, a variation of the flipped classroom, not only ensures the efficiency of personalized learning but also retains the irreplaceable value of face-to-face education in fostering social connectivity and emotional engagement (Bergmann, J., & Sams, A., 2012).

4.3 Strategy for Data Interpretation and Instructional Intervention

A central advantage of digital and intelligent platforms lies in their robust learning analytics (LA) capabilities. Teachers must significantly enhance their data literacy to effectively interpret the learning status reports generated by the platform—such as class-wide heatmaps highlighting frequent errors (e.g., many students confusing "未" and "末"), individual knowledge mastery trajectories, and behavioral data (such as completion time and repetition rates). Teachers should identify common problems and individual differences, and implement targeted interventions accordingly. For instance, they may adjust teaching content and pacing at the class level based on data analysis, or provide customized resources and one-on-one guidance at the individual level. This process completes the instructional cycle from data insights to analytical diagnosis and precise intervention, enabling instructional decisions to shift from subjective experience to objective, data-driven practice.

4.4 Strategy for Sustaining Learning Motivation

A sustainable incentive system is crucial to maintaining motivation among beginning learners. For many students, the initial challenge of Chinese character learning can feel daunting and monotonous; accordingly, gamification mechanisms that integrate extrinsic incentives with intrinsic motivation are key. Digital platforms can motivate learners by awarding points, badges, and rankings, which provide timely feedback and enhance feelings of achievement while meeting psychological needs. According to Self-Determination Theory, providing a variety of open-ended tasks can satisfy the need for autonomy; establishing clear advancement pathways and certificates of competence can address the need for competence; and organizing team-based learning challenges can foster a sense of relatedness. By transforming learning from a passive obligation to an active exploration, such mechanisms help foster durable intrinsic motivation among learners (Ryan, R. M., & Deci, E. L., 2000, pp. 68-78).

5. Reflection and Prospects

Digital and intelligent technologies hold immense potential for transforming the paradigms of Chinese character instruction, yet their application in educational practice still faces multiple challenges. First, digitally empowered Chinese character pedagogy imposes higher demands on teachers' digital literacy; thus, the cultivation and training of teachers has become an urgent issue that must be addressed. Second, the development and implementation of digital and intelligent platforms specifically tailored for Chinese character instruction remain inadequate; the imbalance between the supply of and the demand for digital resources constitutes a tangible obstacle for the practical empowerment of instruction through digital technologies. Third, the application of such technologies raises certain risks related to data privacy. In particular, the protection of user privacy in the collection, storage, and analysis of learners' handwriting trajectories, speech data, and learning analytics is a pressing concern that warrants close attention.

Looking forward, digital and intelligent technology empowerment is poised to provide more efficient instructional paradigms and richer educational resources for elementary-level Chinese character teaching. Generative AI will be able to create highly personalized opportunities for character acquisition based on learners' interests; metaverse technologies may construct fully immersive worlds for character learning, realizing the ultimate scenario of "learning by applying and applying to reinforce learning"; and the introduction of affective computing holds the promise of allowing systems to recognize learners' emotional states and dynamically adjust instructional strategies. Ultimately, this will help create a new ecosystem of Chinese character instruction characterized by the integration of human-computer collaboration and emotional intelligence.

6. Conclusion

This study has conducted an in-depth exploration of the practical pathways and strategies for digitally and intelligently empowered elementary Chinese character instruction. By establishing an integrated four-dimensional empowerment framework encompassing "recognition, reading, writing, and application," and by implementing strategies such as redefining the teacher's role, constructing blended teaching models, and data-driven instructional interventions, this approach effectively addresses the traditional challenges faced by learners, namely, difficulties in memorizing orthographic forms, mastering pronunciation, achieving writing accuracy, and applying characters flexibly. Although objective challenges remain, such as the urgent need to improve teachers' digital literacy and the incomplete development of digital teaching resources, the deep integration of digital and intelligent technologies with pedagogy is poised to propel international Chinese education to a new stage of development.

References

Bergmann, J., & Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Oregon: International Society for Technology in Education.

Cui, X. L. (2024). The Impact of "Handwriting" and "Typing" on Chinese Character Learning and Related Research Perspectives. *Journal of Yunnan Normal University*, *22*(05), 11-19.

Feng, L. Y. (2010). On the Teaching of Chinese Characters at the Elementary Level of Chinese as a Foreign Language. *Chinese Character Culture*, *2010*(05), 92-96.

Guo, T. (2019). Research on the Characteristics and Development of Stroke Errors in Chinese Characters by Non-Chinese Background International Students. *Journal of Yunnan Normal University*, *17*(02), 19-24.

Jiakai, Z., Gege, L., Qinglin, H. et al. (2022). Augmented Reality in K–12 Education: A Systematic Review and Meta-Analysis of the Literature from 2000 to 2020. *Sustainability*, *14*(15), 9725. https://doi.org/10.3390/su14159725

Kapp, K. M. (2012). *The Gamification of Learning and Instruction: Game-based Methods and Strategies for Training and Education*. San Francisco: Pfeiffer. https://doi.org/10.1145/2207270.2211316

Li, J. L. (2003). Investigation on the Problems of Chinese Character Acquisition by International Students. *Journal of Zhoukou Normal University*, *2003*(01), 110-111.

Liu, J. T. (2010). Analysis of the Phenomenon of "Knowing Words but Not Characters" in Teaching Chinese as a Foreign Language. *Talent*, *2010*(25), 118.

Ministry of Education of the People's Republic of China. (2018). Notice of the Ministry of Education on Printing and Distributing the "Education Informatization 2.0 Action Plan" (Jiao Ji [2018] No. 6)[EB/OL]. Retrieved from http://www.moe.gov.cn/srcsite/A16/s3342/201804/t20180425_334188.html

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68-78. https://doi.org/10.1037/0003-066X.55.1.68

Tian, H. (2024). Application Path of Brain-Computer Interface (BCI) in International Chinese Character Teaching. *Journal of Yunnan Normal University*, *22*(02), 85-92.

Wang, Y. L. (2019). Chinese Character Acquisition and Teaching Strategies for International Students at the Elementary Level. *Think Tank Era*, *2019*(52), 188-189.

Wei, S. Y. (2024). Research on the Construction Strategy of International Chinese Character Teaching Path in the AI Era. *Chinese Character Culture*, *2024*(24), 75-77.