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The Application of Artificial Intelligence in English Learning for Chinese Preschool Children: Based on the Zone of Proximal Development Theory

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Abstract:

The Zone of Proximal Development (ZPD) theory elucidates the gap between a learner's actual developmental level—reflected in their ability to solve problems independently—and their potential developmental level—achieved when solving problems with guidance, providing a crucial theoretical framework for scaffolding instruction in second language acquisition for preschool children. Concurrently, the advent of artificial intelligence (AI) in education demonstrates transformative potential, particularly in facilitating personalized and adaptive learning experiences. This paper conducts a comprehensive analysis of AI applications in English learning for Chinese preschool children, grounded in the ZPD theory. Employing a combination of theoretical review and case analysis, the study addresses three core questions: the theoretical foundations and relevance of ZPD; the current state of AI implementation in this specific context; and practical pathways for integrating AI with ZPD theory. Findings indicate that while AI applications are emerging, they often lack a robust theoretical basis. Findings suggest AI can enhance language acquisition by providing dynamic assessment, personalized scaffolding, and developmentally appropriate challenges. This integration holds promise not only for improving linguistic competence but also for fostering cognitive and socio-emotional development, thus offering a novel intelligent paradigm for optimizing early childhood English education in China.

Keywords: Artificial Intelligence (AI); English Language Learning; Zone of Proximal Development (ZPD); China

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1. Introduction

The early childhood period represents a critical stage for second language acquisition. Research has confirmed that preschool children exhibit physiological advantages for foreign language learning, with no adverse impact on their native language development [1, 2]. In China, factors growing global influence of Chinese culture, the successful hosting of the Olympic Games, and the accelerating pace of globalization have fuelled a surge in demand for preschool English education. Nevertheless, this sector continues to face significant challenges, including teacher shortages, ambiguous educational concepts, and a lack of immersive language learning environments [1, 2]. The Zone of Proximal Development (ZPD) theory, proposed by Vygotsky, defines the gap between a learner's independent problem-solving capacity and their ability to solve problems under guidance, underscoring the importance of personalized instructional support [3,4]. Concurrently, artificial intelligence (AI) technology is revolutionizing educational practice through personalized learning, data-driven interventions, and adaptive resource deployment [5, 6]. Nevertheless, few studies have integrated ZPD theory with AI applications in Chinese preschool English learning, leaving a significant gap. This study aims to address this gap by exploring three research questions: First, what constitutes the theoretical foundation of ZPD and its relevance to preschool English education? Second, what is the current state of AI application in English learning among Chinese preschool children? Third, how can AI be effectively integrated with ZPD theory to scaffold preschool children's English acquisition? Employing a qualitative research methodology, this paper examines existing literature and practical cases through theoretical analysis and case studies. The significance of this research lies in providing intelligent solutions that leverage AI to implement ZPD principles, thereby enhancing the quality and accessibility of preschool English education in China.

2. Theoretical Foundations of the Zone of Proximal Development (ZPD)

The Zone of Proximal Development (ZPD) is a core sociocultural concept proposed by Vygotsky, describing the gap between a child's actual level of independent problem-solving and their potential level attainable with adult guidance or collaboration with more capable peers [3,4]. This concept underscores the dynamic nature of learning, as well as the pivotal role of social interaction and instructional scaffolding in cognitive development. Within the preschool education context, the ZPD provides a framework for understanding how customized support can maximize learning outcomes. For instance, Cao Wei [3] illustrated how teachers, in autonomous play contexts, identified key intervention points by leveraging the ZPD framework. By posing open-ended questions, they guided children to address challenges, thereby cultivating problem-solving abilities and independent thinking. Similarly, Xu Lili [4] applied ZPD to precision teaching in high school mathematics, demonstrating how diagnostic assessments can identify students' ZPDs and guide instructional strategies. These studies indicate that ZPD is not static but evolves with learner development, requiring ongoing assessment and adaptive instructional support. For preschool English learning, ZPD theory suggests instruction should be designed to slightly exceed children's current level while providing scaffolding to facilitate progress. This aligns with young children's natural inclination to learn language effectively through interactive, context-rich environments [1,2]. Thus, ZPD offers a theoretical lens for designing AI interventions capable of delivering real-time instructional support, personalized challenges, and collaborative learning opportunities.

3. Current State of AI Application in English Learning Among Preschool Children in China

The integration of AI into China's preschool education is advancing rapidly, with English learning being one of the primary application areas. The current landscape comprises a range of AI-powered tools tailored to preschool-aged children (typically 3–6 years old), broadly classified into Intelligent Tutoring Systems (ITS), language learning applications (e.g., Duolingo, English Fun Dubbing), interactive educational robots, and AI-enabled interactive toys and platforms—most of which leverage speech recognition and natural language processing (NLP) technologies [5,6]. The primary user groups are preschool children, with parents and educators serving as facilitators and decision-makers in selecting and utilizing these technologies [6,7]. Xin Wei [7] observes that the proliferation of such tools is driven by enhanced parental awareness of early English education and increased investment in this domain. He observes that a growing number of children have prior exposure to English—including have their own English names—by the time they enter kindergarten.

Regarding learning outcomes, AI applications have been reported to enhance engagement, vocabulary acquisition,

and pronunciation skills through interactive games, immediate feedback, and personalized content pacing [5,6]. For instance, AI can analyze children's speech patterns and provide corrective feedback on pronunciation, serving as a form of scaffolding consistent with the ZPD principle. Adaptive learning platforms, such as the "Squirrel AI" system described by Wang Wenjing [6], integrate online and offline education. They focus on comprehensive online tutoring for K-12 students, where online education is delivered by the system to dynamically assess knowledge mastery. Offline education is conducted by teachers, whose primary responsibilities include pacing instruction, guiding and encouraging self-directed learning, and addressing student inquiries. Systems like this are being adapted for younger learners, dynamically adjusting task difficulty based on data performance—a process that reflects the core of continuous assessment inherent to ZPD. However, current applications reveal several critical issues. First, many existing AI products lack a solid pedagogical foundation, often designed as isolated gamified experiences rather than integrated into coherent curricula grounded in child development or second language acquisition (SLA) theory [1,2]. Second, empirical research on the effectiveness of these AI tools for preschool English learning outcomes, particularly within the Chinese context, remains notably insufficient. Furthermore, as critically noted by Xia Bixue [1] and Sun Wei [2], overreliance on technology must never obscure the essential role of interpersonal interaction and the importance of creating authentic communicative language environments. Creating environments for foreign language learning involves multiple dimensions, with teachers being the most crucial factor. Although AI shows great potential for creating rich language environments, its current implementation often fails to realize the full potential of social constructivist approaches (such as ZPD), tending to prioritize individualized over collaborative learning.

4. Practical Pathways for Integrating AI and the ZPD Principle in Preschool English Education

To effectively leverage AI within the Zone of Proximal Development (ZPD) theory for scaffolding English learning in preschool children requires a deliberate, theory-guided design approach. This integration can be achieved through several interconnected practical pathways, each targeting a specific aspect of the ZPD framework.

4.1 AI as a Diagnostic Tool for Dynamic ZPD Assessment

The foundational step in ZPD-guided instruction is accurately diagnosing children's current level and potential developmental level. AI excels in this domain through continuous, unobtrusive data collection and analysis. By monitoring children's interactions within AI-enabled platforms—including question-answering accuracy, response latency, error patterns, voice recordings, and problem-solving sequences—algorithms generate a detailed, dynamic profile of children's ongoing developmental progress. This constitutes their "actual developmental level" [4]. For instance, AI can identify whether a child persistently confuses specific phonemes (like /θ/ and /s/), struggles with particular grammatical structures, or has mastered a specific vocabulary set. This diagnostic approach transcends simple scoring, similar to the pre-test questions used by Xu Lili [4] to diagnose students' understanding and misconceptions of knowledge, but equally applicable to preschool language learning. The system can algorithmically infer a child's ZPD by identifying "next achievable" skills—tasks the child cannot yet complete independently but can accomplish with targeted support. This continuous assessment process ensures that instructional goals remain within the child's ZPD, making teaching truly "precision-based" [4].

4.2 AI as a Provider of Personalized and Adaptive Scaffolding

Once the ZPD is identified, artificial intelligence can implement Vygotsky's concept of scaffolding with a level of precision, consistency, and meticulousness that is difficult to achieve manually in a classroom setting. In an AI context, scaffolding entails providing timely, adjustable, and temporary support that is systematically withdrawn as children's abilities grow, ensuring learners are able to continuously practice within their ZPD [5,3]. This support mechanism can be multimodal and context-aware, far surpassing static teaching aids. For example, when a child struggles to recall the word "apple" during a virtual story activity, AI might first offer a subtle visual cue (e.g., a semi-transparent apple image overlaid on the scene). If the child remains hesitant, the AI system could provide an auditory cue (a clear pronunciation of the word). If the challenge persists, the AI can simplify the task itself, transforming an open-ended question into a more manageable binary choice (e.g., "Is this an apple or a banana?"). This layered, dynamic support system is crucial for keeping children within their "zone of development," effec-

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tively preventing frustration from overly difficult tasks and boredom from overly easy ones, thus safeguarding their intrinsic motivation for learning [1].

Beyond reactive scaffolding, AI can proactively personalize the learning experience throughout the entire educational journey. It can curate or even generate stories, songs, and interactive games that precisely match children's Zone of Proximal Development (ZPD) while aligning with their individual interests and cultural backgrounds—such as such as dinosaurs, history, vehicles, fairy tales, and local traditional festivals [7]. This alignment significantly boosts students' intrinsic motivation and engagement—key factors repeatedly emphasized in the literature for sustaining young learners' attention and effort [1,2,7]. For instance, if a child shows strong interest in animals, AI can generate a personalized unit where the child learns colors and sizes by helping a "baby elephant" find its mother, embedding language goals within captivating, interest-driven narratives.

Furthermore, AI-driven scaffolding can be extended to model and support higher-order cognitive and linguistic strategies. Drawing on pedagogical principles emphasized by Sun Wei [2] and Xia Bixue [1]—namely, prioritizing children's sensory engagement in knowledge construction over excessive focus on knowledge acquisition, and fostering language environments that cultivate communicative desire—AI can provide scaffolding for the learning process itself. It can simulate "thinking aloud" strategies—such as inferring new word meanings from pictorial contexts or combining known words into simple sentences—thereby making implicit cognitive processes explicit. This aligns with a key component of the guidance aspects of the ZPD, where the knowledgeable other is replaced by AI instruction, which not only demonstrates the correct answer but also the process of arriving at it. This metacognitive scaffolding is crucial for cultivating independent learning skills.

Finally, the adaptive nature of AI ensures that scaffolding is not a one-way street but part of a continuous feedback loop. The system constantly measures the effectiveness of its support. If a particular type of prompt—such as a visual cue—consistently works for a child, the system will employ that pattern in the future. Conversely, if the support fails to trigger student progress, the AI can adjust its instructional strategy based on the student's current state—for example, breaking tasks into smaller, more manageable steps to facilitate understanding. This creates a truly responsive, self-optimizing instructional environment that embodies the dynamic and diagnostic essence of precision teaching demonstrated by Xu Lili [4], applying it to the field of early language acquisition.

5. Conclusion

This study systematically examines the integration of artificial intelligence with the Zone of Proximal Development (ZPD) theory in the context of English learning among Chinese preschool children. The analysis reaffirms the ZPD's strong explanatory and guiding utility in designing developmentally appropriate language instruction—one that is grounded in diagnostic assessment and instructional scaffolding. A review of the current landscape indicates that while AI applications are increasingly prevalent and hold promise for personalization and learner engagement, their development and implementation often lack deep theoretical integration—especialy with sociocultural principles such as the ZPD. The proposed practical pathways—positioning AI as a dynamic evaluator, personalized scaffolding provider, and interaction facilitator—chart a course for more meaningful integration. This approach holds promise for effectively addressing persistent challenges in the field, such as disparities in teacher proficiency and scarcity of immersive environments, by delivering scalable, intelligent solutions that both adapt to and support children's holistic development. However, this study is not without limitations. It relies primarily on theoretical analysis and existing literature synthesis, thus necessitating future empirical validation via rigorous qualitative and quantitative research in real-world preschool settings. Furthermore, the present research is based solely on Chinese preschool children; future studies should expand the sample scope. Future research directions should include assessing the long-term impact of the AI-ZPD integration model on language proficiency and cognitive development, as well as developing concrete design frameworks for creating ZPD-aligned AI tools. Despite these limitations, this paper presents a coherent, theory-grounded vision for the field, proposing a long-term blueprint for leveraging advanced technology to enhance early childhood education in ways that are not only effective and fundamentally human-centered .

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