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The integration of VR technology in Early Childhood Education: Review of Impacts and Challenges

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ABSTRACT

Objective: *This systematic review explores the integration of Virtual Reality (VR) technology in early childhood education (ECE) in China, with the aim of identifying its pedagogical impacts, implementation challenges, and ethical considerations.* ***Method:*** *Guided by the PRISMA framework, a comprehensive search was conducted across CNKI, Wanfang, and ScienceNet databases using targeted keywords related to ECE, VR technologies, and preschool-aged children. Eighteen empirical and conceptual studies published between 2019 and 2023 were selected for thematic analysis.* ***Results:*** *Findings reveal that VR enhances children's learning engagement, enriches instructional contexts through immersive simulations, and supports personalized learning paths with real-time feedback. However, challenges include potential risks to visual health, developmental appropriateness of content, and limited teacher preparedness. Ethical concerns such as overreliance on virtual experiences and weakened emotional development were also noted.* ***Novelty:*** *This review contributes novel insights by offering a China-specific synthesis of current VR applications in preschool education, emphasizing the importance of establishing age-specific technical standards, interdisciplinary content development, and policy safeguards. The study calls for a balanced "virtual-reality complementarity" approach to align technological innovation with holistic child development.*

INTRODUCTION

Preschool education constitutes a critical period for children's physical and mental development, laying the foundation for cognitive, emotional, and social growth. With the rapid advancement of virtual reality (VR) technology, its educational applications have progressively permeated from higher education to early childhood education, injecting innovative vitality into traditional teaching paradigms (Ning & Huang). Simultaneously, limitations in conventional early education settings have become increasingly apparent—monotonous teaching models, difficulties in visualizing abstract concepts, lack of cross-cultural experiences, and outdated spatial environments—all of which hinder effective engagement and intrinsic motivation in young learners (Liu et al., 2022). Consequently, the integration of VR technology with early education has gained urgent relevance. However, societal concerns have emerged regarding whether premature adoption of VR might diminish children's real-world perception and trigger an "erosion of authentic childhood experiences. (Dai & Dai, 2022). This paper seeks to clarify the potential value and risks of combining VR technology with ECE, examine its role in resolving traditional classroom challenges and respond to societal concerns about "excessive technological intrusion into childhood, systematically examines the dual dimensions of VR 's impacts and challenges in preschool education, aiming to provide theoretical insights for sustainable technology-enabled early education practices.

Research Question

1. Research question 1 : What are the Impacts of Integrating VR Technology into Preschool Education Curriculum?
2. Research question 2 : What are the Challenges of Integrating VR Technology into Preschool Education Curriculum?

RESEARCH METHOD

To ensure a comprehensive and systematic retrieval of relevant studies, this review employed a structured search strategy guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Selcuk, 2019). The literature search was conducted across three major Chinese academic databases: CNKI (China National Knowledge Infrastructure), Wanfang Data, and ScienceNet.cn. These databases were selected due to their extensive coverage of educational research published in mainland China.

The search strategy utilized a combination of Boolean operators and thematic keywords, grouped into three categories:

1. Early childhood education terms: “早教” (early education), “学前教育” (preschool education), “早期教育” (early childhood education);
2. Technology-related terms: “VR 技术” (VR technology), “虚拟现实技术” (virtual reality), “VR 设备” (VR devices), “信息技术” (information technology);
3. Target population descriptors: “儿童” (children), “幼儿” (young children), “童年” (childhood), “学龄前儿童” (preschool children).

The time frame was restricted to studies published between January 2020 and December 2024 to capture the most recent developments in the integration of VR technology within Chinese early childhood education contexts. Only peer-reviewed journal articles written in Chinese and focusing on the application of VR or virtual reality technologies in the preschool education domain in China were considered. Dissertations, conference abstracts, and non-academic articles were excluded.

The initial search yielded 156 articles. After removing duplicates and screening titles and abstracts for relevance, 46 articles were selected for full-text review. Based on inclusion and exclusion criteria—namely, (1) empirical or conceptual studies focused on VR in ECE settings, (2) relevance to cognitive, instructional, or ethical dimensions, and (3) alignment with the Chinese early childhood education context—a final 18 studies were retained for thematic analysis.

Data analysis

A thematic analysis approach was employed to synthesize findings from the final set of 18 articles. Following Braun and Clarke’s (2006) six-step method, the process involved: (1) familiarization with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) producing the report.

Each article was read multiple times to extract salient information related to (1) the potential educational value of VR in preschool education; (2) implementation challenges

and limitations; and (3) ethical and developmental concerns in the Chinese context. Key data were categorized inductively and refined through iterative comparison. Three major themes emerged:

1. Impacts of VR on learning engagement and personalization;
2. Developmental and instructional challenges of VR integration;
3. Policy, ethical, and equity considerations in technology use.

The findings reflect current scholarly discourse in China regarding the opportunities and risks of introducing immersive technologies into preschool curricula. By narrowing the scope to Chinese-language literature over the past five years, the review ensures contextual relevance and captures ongoing national efforts in technological innovation and early childhood education reform.

RESULTS AND DISCUSSION

This study aims to systematically explore the dual impacts and practical challenges of integrating VR technology into early childhood education (ECE) curricula, providing theoretical insights for balancing technological empowerment with children's developmental needs. Through a literature analysis, the research focuses on two core issues: (1) the comprehensive effects of VR on children's cognitive, emotional, and social development, and (2) the critical constraints to address during technological implementation.

Question 1: What are the Impacts of Integrating VR Technology into Preschool Education Curriculum?

Positive Impacts:

1. Enhancing Children's Engagement

Virtual Reality (VR) offers immersive, multisensory experiences that surpass the limitations of traditional teaching materials. By enabling children to explore virtual environments through first-person perspectives, VR enhances perceptual vividness and emotional resonance, thereby fostering intrinsic motivation and spontaneous engagement in learning tasks. For instance, children can virtually visit outer space, underwater ecosystems, or historical settings, which not only cultivates curiosity but also provides authentic, emotionally rich contexts for learning. Studies indicate that such sensory-rich, immersive experiences activate multiple neural pathways, leading to increased attentional focus, prolonged task persistence, and elevated enthusiasm for knowledge acquisition (Wang, 2024). Moreover, the simulation of social scenarios—such as classroom cooperation, family role-play, or conflict resolution—within VR environments allows young learners to engage in authentic, consequence-driven social interactions (Bailenson, 2018). This supports the development of empathy, turn-taking, emotional regulation, and other core social-emotional competencies essential in early childhood.

2. Enriching Instructional Content and Learning Contexts

One of the most transformative impacts of VR is its capacity to recreate complex, interactive, and authentic learning environments. By integrating problem-solving

elements and real-life simulations into instructional design, VR supports situated learning and encourages preschoolers to engage in exploration-based, inquiry-driven activities. For example, children can "walk" through a rainforest to study plant life cycles or "experience" different professions in a career exploration module. This multimodal, dynamic approach not only enriches learning content but also promotes cross-disciplinary understanding and real-world knowledge transfer (Wang, 2024; Chen, 2024). Additionally, VR helps bridge the gap between abstract concepts and concrete understanding, which is particularly valuable for young children whose cognitive development is still largely perceptual and experiential. For instance, mathematical concepts such as shape, size, and quantity can be taught through virtual manipulations in a three-dimensional space, enhancing cognitive retention and transfer.

3. Delivering Personalized Learning Experiences

VR platforms often incorporate AI-driven algorithms that adapt content in real time to match each learner's individual pace, preferences, and developmental stage. Through customizable pathways, children can navigate differentiated activities, adjusting challenge levels based on their readiness and confidence. This scaffolding aligns with Vygotsky's Zone of Proximal Development (ZPD), offering just-in-time support and promoting self-directed learning behaviors (Chen, 2024). Teachers benefit from rich data analytics provided by VR systems, including metrics on engagement duration, task completion patterns, and response accuracy. Such data enables timely pedagogical adjustments, ensuring that instruction is not only personalized but also responsive and evidence informed. The diagnostic insights contribute to early identification of learning difficulties and more precise intervention strategies.

Negative Impacts:

1. Fostering Over-dependency

While VR presents powerful pedagogical affordances, overreliance on such immersive tools can inadvertently suppress children's cognitive autonomy and hinder the development of higher-order thinking skills. The inherently guided nature of many VR applications may reduce opportunities for divergent thinking, open-ended problem solving, and imaginative play—core pillars of early childhood education. Excessive screen time in virtual environments can also displace time spent in real-world exploration and interpersonal communication, potentially stunting social development and reducing emotional resilience (Lei & Wang, 2023). The novelty effect of VR may condition children to expect constant stimulation, which can fragment attention spans and impair sustained focus during non-digital tasks. The reduced tolerance for ambiguity and delayed gratification may also manifest in classroom settings, undermining executive function development.

2. Impairing Visual Health

Children's visual systems are still maturing, making them particularly vulnerable to strain from prolonged use of head-mounted displays (HMDs). VR experiences typically require sustained near-point visual focus and limited ocular movement, increasing the risk of visual fatigue, convergence insufficiency, and even the early onset

of myopia (Chen, 2024). Studies have also raised concerns about balance disturbances, dizziness, and motion sickness (i.e., "cybersickness"), particularly in children under the age of seven.

Physical inactivity is another indirect consequence of VR-based learning. While some applications encourage movement (e.g., gesture-based interactions), many VR experiences are sedentary in nature. This could limit opportunities for gross motor development, an essential domain in early childhood learning.

3. Undermining Emotional Nurturing

Although VR can offer emotionally engaging content, it cannot replicate the nuanced, affective bonds formed through human relationships. Elements such as eye contact, voice modulation, and physical proximity play vital roles in building trust, empathy, and a sense of security in young children. Overexposure to emotionally simulated avatars or automated feedback may desensitize children to authentic emotional cues, thereby impairing their socio-affective maturation (Zhang et al., 2021). Emotional learning in early childhood is deeply embedded in relational experiences with caregivers and teachers. If VR becomes a primary medium for instruction, it may marginalize these essential human interactions, diminishing children's capacity for reciprocal empathy, social responsibility, and moral development.

Question 2: What are the Challenges of Integrating VR Technology int Preschool Education Curriculum?

Although VR technology has shown significant potential in improving teaching quality, its integration into preschool education curriculum still faces multiple challenges. These challenges cover multiple aspects such as health risks, content adaptation, teaching control and technical resources, and require educators, policymakers and technology developers to work together to achieve its safe, effective and sustainable application.

1. Time Management

Preschool children are in a critical stage of ocular and neurological development. Extended exposure to near-field visual stimuli, such as those presented through head-mounted displays (HMDs), may lead to visual fatigue, impaired accommodation response, and accelerate the onset of pediatric myopia (Chen, 2024; He et al., 2021). Unlike traditional screen devices, VR environments typically require intense focus at a fixed focal distance, limiting ocular micro-movements and increasing strain on the visual system.

Therefore, it is imperative to establish evidence-based usage guidelines tailored to developmental stages. Research suggests that for children under the age of 6, individual VR sessions should not exceed 10 minutes and should be interspersed with substantial periods of real-world activity to recalibrate sensory balance (American Academy of Pediatrics, 2020). Moreover, VR content developers and hardware manufacturers must ensure that devices adhere to ergonomic design standards—such as appropriate interpupillary distance (IPD), high-resolution displays, and adjustable brightness—to mitigate visual health risks.

2. Content Appropriateness

Young children exhibit limited cognitive ability to distinguish between simulated and actual experiences. Inadequately designed VR environments may blur the boundaries between virtuality and reality, potentially resulting in spatial disorientation, narrative confusion, or the formation of misconceptions about physical laws (e.g., gravity, causality) (Liu, 2024; Pianta et al., 2020). Curriculum developers must therefore embed cognitive anchors—visual markers, narrative transitions, or tactile cues—that reinforce distinctions between virtual and physical domains. Furthermore, content must align with principles of developmental psychology, ensuring that scenarios are not overly abstract, emotionally overwhelming, or cognitively dissonant for the target age group. A developmentally appropriate VR experience should scaffold children's understanding of reality while stimulating imagination, not replace or distort it. Age-appropriate content design also demands interdisciplinary collaboration across early childhood educators, developmental psychologists, and XR designers. This ensures that VR experiences are both pedagogically sound and psychologically safe.

3. Instructional Control

Effective VR integration hinges not only on content quality but also on teachers' capacity to mediate and regulate the use of technology within instructional settings. Educators must master three interrelated dimensions of control (Zhang et al., 2021):

1) **Developmental Scheduling** – Determining appropriate frequency and timing of VR sessions based on children's age, attention span, and physiological tolerance.
2) **Content Curation** – Selecting or designing VR modules that are explicitly aligned with curricular goals, learning standards, and individualized learning trajectories.
3) **Technical Management** – Rapidly responding to device malfunctions, user discomfort, or behavioral dysregulation during sessions (e.g., dizziness, distraction, overstimulation).

However, many early childhood teachers lack the training or confidence to integrate emerging technologies effectively. There remains a substantial gap in professional development programs that equip preschool educators with the necessary technological pedagogical content knowledge (TPACK) to critically evaluate, adapt, and troubleshoot VR applications in real-time instructional contexts

4. Technological and Equipment Limitations

The integration of VR in early childhood settings is significantly constrained by financial and infrastructural barriers. High-quality VR systems—including standalone HMDs, motion sensors, spatial tracking equipment, and interactive content licenses—demand considerable upfront investment (Liu et al., 2023). For many public kindergartens, especially in underfunded or rural regions, these costs remain prohibitive.

Moreover, ongoing maintenance (e.g., device calibration, software updates, hygiene management) requires additional human and material resources. The development of age-specific VR educational content also faces bottlenecks due to limited market incentives and high production costs. Unlike general K-12 or adult education markets, early childhood VR content requires stricter compliance with developmental standards,

leading to a shortage of high-quality, research-informed applications suitable for this age group. Infrastructural constraints—including limited classroom space, unstable internet connections, and lack of dedicated technical support—further hinder large-scale or consistent implementation

Recommendations

To achieve sustainable and developmentally appropriate integration of VR technology into early childhood education (ECE), a multi-pronged optimization strategy is required. This strategy should focus on technological adaptation, pedagogically sound content development, and the establishment of robust policy and ethical frameworks.

Technological Improvements

Current mainstream VR hardware is predominantly designed for adult users, with limited consideration for the cognitive and physiological characteristics of young children. To address this, future VR hardware development for ECE should prioritize:

1) **Simulated Real-Life Situations**: VR technologies should authentically replicate real-world environments and everyday experiences (e.g., visits to farms, space explorations, or weather simulations) to reinforce learning transfer between virtual and physical contexts. This approach promotes a holistic learning atmosphere and reduces abstract detachment often associated with digital instruction (Ge, 2020; Zhu & Wang, 2024).
2) **Child-Friendly VR Equipment**: Fully immersive headsets may isolate children from their surroundings and hinder social development. Instead, development of semi-immersive VR glasses tailored to young users—lightweight, open-sided, and ergonomically designed—can preserve real-world awareness and mitigate visual health risks (Liu, 2024).
3) **Natural Interaction Design:** Replacing traditional controllers with gesture recognition and voice commands enables more intuitive interaction for preschoolers, many of whom are still developing fine motor coordination (Fu, 2023; Zhang et el., 2020). This enhances user accessibility and reduces physical strain.
4) **Built-in Usage Safeguards:** VR systems should be embedded with automatic session timers, visual fatigue alerts, and adaptive brightness controls. These features can help enforce safe exposure limits for young children (e.g., sessions ≤10 minutes, resolution ≥4K), thus protecting their visual and neurological health (Lei & Wang, 2023).

Content Development Guidelines

A critical challenge in VR-based ECE lies in designing developmentally appropriate and pedagogically valid content. The following principles should guide VR content creation:

1) **Reality-Virtuality Distinction:** Content should include embedded cognitive markers—such as transitions, reflective prompts, or visual cues—to help children distinguish between virtual experiences and real-life events. This helps prevent reality confusion, which can impair children's spatial-temporal awareness and cognitive integrity (Liu, 2024).

2) **Age-Appropriate Curriculum Design:** VR learning modules should align with the developmental stages and learning goals of children aged 3–6. For example, modules designed for 3-year-olds might emphasize sensorimotor exploration and color recognition, while modules for 5–6-year-olds could introduce problem-solving or early STEM concepts (Chen, 2024).
3) **Technical Parameter Standards:** Developers must adhere to child-specific standards in screen resolution, frame rate, audio levels, and interface simplicity. Regulatory authorities should publish clear device parameter guidelines to ensure safety and usability for ECE learners (Lei & Wang, 2023).
4) **Ethical Design and Behavioral Boundaries:** Ethical guidelines should prohibit the inclusion of inappropriate content (e.g., violence, competition-centric narratives) and promote nurturing experiences that reflect core values such as empathy, cooperation, and inclusion. A behavioral framework for VR use—complemented by teacher and parental guidance—must be established to maintain developmental integrity (Shim, 2023)

Policy and Ethical Frameworks

Ensuring equitable access, responsible use, and pedagogical value of VR technology in preschool settings requires systemic support across policy, market, and institutional levels.

1) **Standardization of VR Resources:** Government and industry stakeholders should collaborate to create standardized benchmarks for VR product certification, including content validation processes, child safety criteria, and usage protocols.
2) **Market Expansion and Cost Reduction:** High costs remain a barrier to widespread adoption in public early childhood institutions. Policies that encourage VR product marketization and subsidize hardware acquisition can accelerate integration, especially in under-resourced regions (Wu, 2024).
3) **Home-School Co-Education Systems:** A dedicated parental companion app should be developed to synchronize VR learning data, monitor usage frequency, activate "forced rest" reminders, and filter inappropriate content. This empowers caregivers to actively participate in and supervise children's digital learning routines.
4) **Teacher Training and Professional Development:** Teachers must be equipped with both technical competencies and pedagogical strategies to implement VR responsibly. Continuous professional development programs should be offered, focusing on: Classroom-VR integration planning, Device troubleshooting, Emotional moderation and sensory balance, Reflective assessment based on VR learning data.
5) **Collaborative VR Task Frameworks:** For social-emotional development, VR content designers should create collaborative task-based experiences to foster communication, perspective-taking, and cooperation among peers (Cheng, 2024).

CONCLUSION

Fundamental Finding : This study systematically examines the dual impacts and practical challenges of integrating VR technology into early childhood education (ECE), offering critical insights for achieving a sustainable balance between technological innovation and holistic child development. The findings reveal that VR technology holds transformative potential for enriching ECE practices. Immersive environments, such as virtual social simulations and cross-cultural experiences, enhance children's engagement, creativity, and social-emotional skills, while personalized learning pathways empower educators to address individual learning needs dynamically. Furthermore, VR's ability to transcend physical limitations enables contextualized knowledge acquisition, addressing longstanding issues like resource inequality and abstract concept visualization in traditional classrooms. However, these benefits are counterbalanced by significant risks, including overreliance on virtual interactions, vision health concerns, and the inadequacy of programmed emotional exchanges in nurturing authentic human bonds. **Implication :** To mitigate these challenges, a "virtual-reality complementarity" framework is proposed. This framework positions VR as an extension of real-world activities rather than a replacement, emphasizing the design of hybrid learning models (e.g., combining VR simulations with hands-on experiences) to reinforce experiential learning. Policymakers, educators, and technologists must collaborate to develop stringent industry standards, including content review mechanisms and device safety protocols, tailored to the developmental needs of 0–6-year-olds. **Limitation :** The study identifies three critical implementation challenges: (1) establishing age-specific technical standards (e.g., usage duration, device resolution) to safeguard children's health; (2) designing cognitively appropriate content to prevent reality confusion or harmful influences; and (3) enhancing teachers' capacity to integrate VR as a supplementary tool while maintaining pedagogical control. **Future Research :** Future research should prioritize longitudinal studies on VR's long-term effects and explore adaptive strategies to align technological advancements with the irreplaceable value of real-world human interactions in early childhood development (Chen et al., 2020). Meanwhile, pay attention to the combination of emerging technologies, such as artificial intelligence, Internet of Things, with VR technology to create a more intelligent and personalized learning environment for early education.

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