Proceedings of ICEIPI 2025 Symposium: AI Am Ready: Artificial Intelligence as Pedagogical Scaffold
DOI: 10.54254/2753-7048/2025.CB23803

The Potential and Challenges of Virtual Reality Technology in Early Childhood Education

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Abstract: In recent years, the application of virtual reality (VR) technology in early childhood education has aroused great interest. However, the comprehensive analysis of its potential and challenges is still insufficient. This paper reviews empirical research and provides an in-depth analysis of how VR technology is being implemented in this education sector. Research shows that virtual reality technology is expected to be applied in many aspects, especially in the cognitive development and memory enhancement of young children. The technology also demonstrates effectiveness in special education contexts, helping children with developmental delays improve social interaction skills. However, significant barriers persist, including hardware limitations for small users, insufficient teacher training programs, and concerns about prolonged exposure effects on developing brains. In view of these findings, this paper puts forward some specific suggestions. The overall goal is to provide practical guidance for field applications and further research pursuits, thereby aiding the progress of early childhood education within the field of virtual reality.

Keywords: Virtual Reality (VR) Technology, Preschool Education, Educational Innovation

1. Introduction

With the progress of the times, the education field is undergoing profound changes, and various emerging technologies are constantly being updated, bringing new vitality to the innovation of education models. Early childhood education, as the foundation of a country's education, is also the most important step in educational reform. Virtual reality (VR) technology, as a highly influential emerging field, has gradually become mainstream in early childhood education due to its immersive experience, high interactivity, and situational creation ability [1]. Childhood is a critical period for the cognitive, emotional, and social development of young children. Traditional early childhood education mainly relies on teacher-textbook teaching and simple game activities. Although these methods can provide some needs for young children, many abstract viewpoints cannot be directly presented to them through traditional means [2]. The emergence of VR technology has brought hope for breaking through these limitations and opening up new learning modes for young children. However, incorporating VR technology into education is not without its difficulties. Based on this, this article summarizes and analyzes the challenges faced by VR technology in the process of early childhood education application, and proposes corresponding solutions, hoping to be helpful for the future development of young children.

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2. Virtual reality technology

2.1. Overview of virtual reality technology

Virtual reality technology, abbreviated as VR, is defined as a computer simulation system that can create and experience a virtual world, providing users with environmental opportunities that feel similar to real-world objects and events [3]. The three main characteristics of VR technology are immersive, interactive, and imaginative [4]. Therefore, VR technology can provide real-time interaction through various sensory stimuli such as visual, auditory, tactile, etc., bringing an immersive experience to the experience.

2.2. Application of virtual reality technology

With the development and improvement of VR technology, VR technology has begun to emerge in various fields such as education, medicine, language learning, and sports training [5,6]. For example, according to Harrington et al.'s research, VR technology has broken the process of traditional Chinese medicine students watching videos to learn in surgical education. With the aid of VR technology, surgical simulations can be carried out in an immersive way [7]. The key factor contributing to the popularity of VR in the educational field lies in its immersive and interactive features. When students immerse themselves in the learning environment created by VR, they have a sense of realism and imagination that traditional books cannot achieve. Therefore, at present, most researchers maintain a positive attitude towards VR in the field of education, believing that VR represents an "innovation" in educational tools [8]. For example, VR technology can be integrated with mobile phones, tablets, or other devices and teachers' teaching processes, using these devices to help students see places and cultures that traditional teaching methods cannot see with their own eyes.

Currently, the majority of the comprehensive research regarding the application of VR technology in the educational domain mainly centers on K-12 and higher education, with a deficiency of studies on the potential of VR technology in the field of early childhood as well as the challenges it is currently encountering. Therefore, it is of vital importance to delve into the area of early childhood education.

3. Potential applications of VR technology

The period from 0 to 6 years old is a crucial and critical stage for children's cognitive development. Scholars and experts need to think deeply about how to skillfully use VR technology to improve children's learning interests and improve children's cognitive abilities. This paper will systematically analyze the specific application of virtual reality (VR) technology in early childhood education, and discuss its impact on children's cognitive ability and help.

3.1. Creating learning situations to improve cognitive ability

When virtual reality technology is applied in the field of teaching to create virtual environments, it is important to base it on constructivist theory and situational learning theory. Firstly, constructivist learning theory emphasizes the learner's dominant role in the learning process, believing that the establishment of knowledge and the learner's learning environment need to be mutually constructed [9]. In a virtual learning environment, teachers can use VR to design courses based on their own teaching experience and children's cognitive development characteristics, helping children construct knowledge in the virtual environment and promote their cognitive development. Secondly, situational learning theory emphasizes the importance of learners engaging in real-life or simulated situations. The characteristic of VR technology is that it can simulate various real or virtual situations, enhancing

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children's understanding and cognition of knowledge. For example, in a study by Khan et al., VR technology was used to create a virtual road traffic environment for young children, and the results showed that virtual scenario training created by VR systems can have a positive impact on improving children's cognition [10]. Therefore, creating a virtual learning environment through VR is a very effective method to help young children improve their cognition, and they can creatively learn more knowledge.

3.2. Enhancing attention and memory development

In the cognitive growth stage of young children, there are two important abilities, namely attention and memory [11]. Attention is defined as an individual's ability to concentrate and persist in completing tasks. The theoretical basis of young children's attention mainly comes from the cognitive load theory. The cognitive load theory suggests that the learning process is mainly divided into internal load, external load, and related load [12]. VR technology enhances children's attention by increasing the relevant load. For example, research by Tarng et al shows that immersive environments created through VR can improve memory [13]. Although the research focuses on elementary school students, it also has strong reference value for early childhood education. Meanwhile, another case study also confirmed that VR technology has a positive impact on children's attention. According to Chu's research children's attention time is significantly prolonged in VR environments, showing higher levels of interest and curiosity. The results indicate that VR technology effectively prolongs children's observational attention and improves their cognitive abilities [14]. At the same time, it must be clearly understood that for children, memory is a very important stage in the process of their gradual development from no awareness of things to conscious understanding, and it always occupies a key position in the whole stage of childhood [15]. Memory can be subdivided into sensory memory, short-term memory, and long-term memory [16]. Having a good memory, for young children, is one of the key factors in their future success in learning and life. During the experience, children are more likely to recall the knowledge presented by the environment by 'touching' objects or 'hearing' sounds in the environment [17]. Exercising and improving memory through VR during early childhood can help them cope with learning content more easily in the future. The case study of Araiza et al also provides strong evidence. The results showed that young children's memory was enhanced through the sensory immersion and interactive features of VR technology.

3.3. Social communication and emotional cultivation

Relevant studies have shown that VR technology has achieved the most obvious effects in the field of early childhood education, social communication, and emotional cultivation of therapy. The characteristics of Autism Spectrum Disorder (ASD) are deficiencies in communication, interaction, and emotional abilities. Traditional intervention methods have certain limitations, so VR technology provides a safe environment for young children to practice repeatedly. According to the research provided by Yuan and Ip, VR programs were specifically designed for young children. By designing real-life scenarios, each virtual character can display a variety of rich emotional expressions. Children can observe the expressions of different characters and communicate with each other through joystick operations [18]. After multiple training sessions, the research results showed that young children's recognition of emotions has significantly improved, from an initial accuracy of 30% to around 80%. These studies can fully demonstrate the significant value of VR technology in the field of early childhood education.

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4. Challenges of applying virtual reality technology in early childhood education

4.1. Technical challenges

Through research, it is found that the main problem facing VR technology in the field of education is low screen resolution. Screen resolution is a key factor affecting the visual effects of young children, as lower screen resolutions can cause issues such as blurry images and loss of details. The cognitive ability of young children is currently in the developmental stage, and clear images directly affect their cognition and understanding of seeing things. For example, when teachers use VR technology to teach young children about the characteristics of plants, low-resolution images can affect their accuracy in distinguishing plant details and may also affect their immersion and learning motivation.

Another significant technical issue is the dizziness caused by wearing VR devices. At present, a large number of studies have confirmed that wearing VR devices for a long time can cause symptoms such as dizziness and nausea. Several reasons can cause dizziness in young children. Firstly, the head-mounted device is too heavy. VR head-mounted devices designed for adults do not conform to the growth and development laws of young children. Because the head and neck muscles and bones of young children are still in the developmental stage, the weight of common head-mounted devices on the market often exceeds the range that young children can bear. Therefore, wearing compression on the neck for a long time may cause dizziness in young children.

Secondly, some young children may experience symptoms similar to motion sickness such as dizziness, nausea, and vomiting while using VR devices, mainly due to the inconsistency between visual and vestibular information. Due to the incomplete development of vestibular function in young children, when virtual images quickly switch and rotate while the body remains stationary, the brain finds it difficult to coordinate the differences between the two, and organs such as the gastrointestinal tract are affected by the nervous system, resulting in discomfort reactions. For example, after playing VR simulation flight games, many young children experience unstable walking, standing, and shaking. This is because the acceleration, rotation, and other movements in the virtual environment stimulate the children's vestibular organs, while the body does not move accordingly, disrupting the nervous system's perception and regulation of balance.

4.2. Teacher challenge

At the same time, the problems faced by teachers in VR technology have also been exposed. Firstly, the VR technology ability of teachers is insufficient. Most teachers rarely receive VR technology training in their professional competence and training, and their mastery of VR technology is zero. So, when VR devices or software experience common malfunctions such as system lag, screen flicker, and abnormal sound, teachers often feel helpless. In practical teaching scenarios, once a malfunction occurs, due to the inability of the teaching staff to solve the problem promptly, the teaching plan can only be temporarily changed, resulting in the incomplete implementation of the originally carefully designed teaching process and greatly reducing the teaching effectiveness. Secondly, there are difficulties in teaching design and implementation. Integrating VR technology into teaching objectives requires teachers to redesign activity courses, but currently, there is no mature and comprehensive VR teaching module and method in the field of education. How to design an activity that combines the interactivity and fun of virtual environments with teaching objectives is also one of the challenges currently faced by teachers.

4.3. Increasing cognitive load on young children

In a virtual environment, it is difficult for young children to concentrate on learning objectives. Due to the young age and strong curiosity of young children, being surrounded by various rich scenes and

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functions in VR environments may interfere with their learning of the target. The processing ability of young children is limited. Virtual reality technology, with its immersive and interactive features, enhances children's interest and curiosity in knowledge. However, while VR technology can stimulate children's interest in learning, multi-sensory information transmission such as sound, touch, sight, and tactile sensation may also bring cognitive load to children [19].

4.4. Potential impact on preschool psychological development

Although VR technology can provide diverse virtual experiences, due to the incomplete cognitive development of young children, if they are exposed to realistic VR virtual worlds too early and excessively, it is easy to encounter difficulties in distinguishing between the real world and the virtual world. In daily life, some children may treat virtual objects in VR games as real entities or imitate the behavior of virtual characters, which interferes with their normal cognitive construction and hinders their understanding and mastery of the rules of the real world. For example, young children may be immersed in sadness for a long time after ending their interaction with their favorite virtual pets, which reduces their interest in real-life interpersonal communication and affects their emotional intelligence development and social skills development. In addition, some VR content contains elements of horror and violence, such as thrilling sound effects and bloody scenes, which exceed the psychological tolerance of young children. Even brief contact may leave a traumatic shadow on young children's psychology. Unlike traditional media, VR immersive experiences instantly immerse young children in stimulating situations, leaving them unprepared psychologically. Their psychological defenses are very vulnerable to trauma, and due to the deep memory traces of virtual scenes, young children may be able to get rid of negative emotional entanglements.

5. Solution strategy

5.1. Technical aspect

Encourage technology companies and educational institutions to collaborate and optimize the display parameters of VR devices specifically for the visual characteristics of young children. Improve resolution to meet the clear observation needs of young children. At the same time, establish mandatory safety standards for children's VR devices, covering various aspects such as wearing comfort, non-toxic and harmless materials, etc. The product comes with detailed safety instructions and warning signs. Before use in kindergartens and homes, teachers and parents need to study in detail, guide children to use it correctly, regularly inspect the equipment, prevent safety accidents, ensure children's safety, and enable more kindergartens to be equipped with high-quality VR devices. The government can establish a special creation fund to attract education experts, content creators, animation designers, and other teams to develop diverse, fun, and cognitive VR educational content for young children.

5.2. Protection of children's physical and mental development

It is possible to design VR devices specifically designed for children that conform to ergonomics, reduce weight, reasonably distribute pressure points, and avoid burdening the neck and shoulders of young children. At the same time, establish a standard usage duration of no more than 15-30 minutes per day, and schedule outdoor activities to ensure the physical development of young children. Integrating vision protection features into VR devices, such as timed reminders for rest, simulating changes in real environmental lighting to adjust the eyes, and controlling the intensity of close-range visual stimuli. Before and after VR teaching, teachers organize children to participate in real-life social interaction activities and share virtual experiences and feelings. At the same time, in curriculum

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design, incorporating real-life comparison elements to guide young children in distinguishing between virtual and real.

5.3. Assist teachers in their professional growth

The education department organizes regular and systematic VR technology training, equipment maintenance, and other content, using a mixed online and offline training mode. Online tutorials are provided for learning at any time, and offline practical exercises and expert guidance are arranged to improve teachers' VR technology practical skills and ensure proficient use of equipment for teaching. At the same time, invite education experts to analyze and explain, guiding teachers to master the methods of integrating VR with children's lives and learning experiences. Conduct a special seminar on the transformation of teacher roles and analyze the differences in teacher roles between traditional and VR teaching contexts. Provide training on communication, observation, and adaptability, such as simulating sudden situations in VR learning for young children, training teachers in coping skills, and helping teachers adapt to new roles.

5.4. Optimize cognitive load management

Teachers screen and stratify VR teaching content in advance based on the cognitive level of young children, highlighting core knowledge. Present concisely and intuitively to ensure that young children can effectively absorb and understand. In the design of VR courses, it is necessary to weaken irrelevant stimuli and strengthen the identification of key learning points. Teachers need to guide and ask questions and prompts promptly when children use VR devices to bring their attention back to learning tasks, prevent distractions, and ensure learning effectiveness. At the same time, when designing teaching courses, attention should be paid to establishing VR education content (education, culture, psychology, etc.), developing content standards suitable for young children, with correct values orientation, scientific knowledge, and other dimensions; Conduct a comprehensive screening of VR content in the market, strictly prohibit any content containing violence or other issues from entering the education field, and create a healthy virtual learning space for young children.

6. Conclusion

In summary, VR has its unique characteristics of immersion, interactivity and imagination, stimulates children's curiosity in learning and plays an important role in cultivating children's basic cognitive abilities such as observation, attention and memory. However, there are still some problems to be solved in the application of VR in early childhood education, such as screening and optimizing VR content suitable for children's age, improving the quality and safety of VR equipment, and solving the problems of overweight and dizziness in children's equipment. In the future, in order to give full play to children's learning potential, educators, technology developers, parents and teachers must work together to develop more VR education products that meet children's development needs, so as to make VR technology more brilliant in the field of early childhood education and help children grow healthily.

References

[1] *Neumann, M. M., Keioskie, M. K., Patterson, D., & Neumann, D. L. (2022). Virtual, Augmented, and Mixed Reality: Benefits and Barriers for Early Childhood Education. Childhood Education, 98(4), 68-79.*

[2] *Wang, N., Abdul Rahman, M. N., & Lim, B. H. (2022). Teaching and Curriculum of the Preschool Physical Education Major Direction in Colleges and Universities under Virtual Reality Technology. Computational Intelligence and Neuroscience, 2022, e3250986.*

[3] *Gao, Y., Liu, D., Huang, Z., & Huang, R. (2016). The Core Elements and Challenges of Promoting Learning Through Virtual Reality Technology. Research on Electronic Education, 37 (10), 77-87*

DOI: 10.54254/2753-7048/2025.CB23803

[4] *Ni, L., & Wang, L. (2021). Model Study of VR Technology in the Professional Teaching of Preschool Education. IEEE Xplore.*
[5] *Yoganathan, S., Finch, D. A., Parkin, E., & Pollard, J. (2018). 360° Virtual Reality Video for the Acquisition of Knot Tying Skills: A Randomised Controlled Trial. International Journal of Surgery, 54, 24-27.*
[6] *Parmaxi, A. (2020). Virtual Reality in Language Learning: A Systematic Review and Implications for Research and Practice. Interactive Learning Environments, 31(1), 172-184.*
[7] *Harrington, C. M., Kavanagh, D. O., Wright Ballester, G., Wright Ballester, A., Dicker, P., Traynor, O., Hill, A., & Tierney, S. (2018). 360 ° Operative Videos: A Randomised Cross-Over Study Evaluating Attentiveness and Information Retention. Journal of Surgical Education, 75(4), 993-1000.*
[8] *Di Natale, A. F., Repetto, C., Riva, G., & Villani, D. (2020). Immersive Virtual Reality in K-12 and Higher Education: A 10-Year Systematic Review of Empirical Research. British Journal of Educational Technology, 51(6), 2006-2033.*
[9] *Colliver, J. A. (2002). Constructivism: The View of Knowledge That Ended Philosophy or a Theory of Learning and Instruction? Teaching and Learning in Medicine, 14(1), 49-51.*
[10] *Khan, N., Muhammad, K., Hussain, T., Nasir, M., Munsif, M., Imran, A. S., & Sajjad, M. (2021). An Adaptive Game-Based Learning Strategy for Children Road Safety Education and Practice in Virtual Space. Sensors, 21(11), 3661.*
[11] *Lodge, J. M., & Harrison, W. J. (2019). The Role of Attention in Learning in the Digital Age. The Yale Journal of Biology and Medicine, 92(1), 21.*
[12] *Sweller, J. (2011). Cognitive Load Theory. Psychology of Learning and Motivation, 55(1), 37-76.*
[13] *Tarng, W., Pan, I-Chun., & Ou, K.-L. (2022). Effectiveness of Virtual Reality on Attention Training for Elementary School Students. Systems, 10(4), 104.*
[14] *Chu, Y. (2021). The Application of VR Technology in Traditional Culture and Art Immersive Teaching for Chinese Children. 2021 13th International Conference on Education Technology and Computers.*
[15] *Cowan, N. (2006). The Development of Memory in Childhood. Psychology Press.*
[16] *Baddeley, A. (2012). Working Memory: Theories, Models, and Controversies. Annual Review of Psychology, 63(1), 1-29.*
[17] *Mantovani, F., & Gianluca Castelnuovo. (2025). The Sense of Presence in Virtual Training: Enhancing Skills Acquisition and Transfer of Knowledge through Learning Experience in Virtual Environments. PubliRES - Publications, Research, Expertise and Skills, 167-182.*
[18] *Yuan, S. N. V., & Ip, H. H. S. (2018). Using Virtual Reality to Train Emotional and Social Skills in Children with Autism Spectrum Disorder. London Journal of Primary Care, 10(4), 110-112.*
[19] *Sobel, K. (2019). Immersive Media and Child Development: Synthesis of a Cross-Sectoral Meeting on Virtual, Augmented, and Mixed Reality and Young Children. Future of Childhood. In ERIC. Joan Ganz Cooney Center at Sesame Workshop.*