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Article

A Systematic Review of Virtual Reality as An Educational Technology in Online Education: Evidence from Chinese Universities

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Abstract: Despite the rapid proliferation of online education within Chinese higher education, pedagogical effectiveness remains constrained by diminished engagement and limited interactivity. Virtual Reality (VR) has emerged as a transformative intervention to address these systemic gaps. Adhering to PRISMA guidelines, this study synthesized 23 empirical investigations (2015-2025). The methodological rigor was appraised via the MMAT, followed by a structured narrative synthesis. Findings reveal that VR integrated instruction significantly transcends traditional screen-based modalities in catalyzing motivation, enhancing knowledge retention, and facilitating practical skill acquisition. These gains are most pronounced in STEM, medicine, and architectural design. Crucially, VR's efficacy is primarily moderated by instructional design quality specifically scaffolding and active interactivity grounded in Constructivism rather than hardware alone. While VR offers substantial affordances, its integration is hindered by infrastructural disparities, high costs, and a deficit in faculty technological pedagogical knowledge. Future research should prioritize large scale RCTs to evaluate longitudinal impact and facilitate a paradigm shift toward pedagogy driven integration.

Keywords: Virtual Reality (VR); Online Education; Systematic Review

1. Introduction

1.1 Background and Context

Online education in Chinese universities has undergone rapid expansion over the past decade, fundamentally reshaping higher education delivery models. This growth accelerated dramatically during the COVID-19 pandemic, when universities nationwide transitioned to online platforms (Zhang & Chen, 2023). However, this swift expansion has exposed critical pedagogical limitations inherent in traditional online learning environments. Research consistently identifies insufficient interactivity, low student engagement, and limited opportunities for experiential learning as persistent challenges that undermine the effectiveness of online education (Chen & Bennett, 2012). These issues are particularly acute in disciplines requiring hands-on practice, spatial visualization, or collaborative problem-solving (Yu et al., 2022).

Virtual Reality (VR) technology has emerged as a promising solution to address these fundamental challenges in online education (Laine & Lee, 2024). By creating immersive, interactive three-dimensional environments, VR enables students to engage with learning content in ways that transcend the limitations of conventional screen-based instruction. The technology allows learners to manipulate virtual objects, explore complex spatial relationships, and practice real-world skills in safe, repeatable simulated environments capabilities particularly valuable for STEM education, medical training, and architectural design (López Chávez et al., 2020; Pellas et al., 2020). Grounded in Constructivist Learning Theory, VR enhanced education positions students as active participants who construct knowledge through direct experience and exploration rather than passive recipients of information (Aiello et al., 2012).

The integration of VR into Chinese university online education has become increasingly feasible due to recent technological and economic developments. The cost of VR hardware has decreased substantially, making institutional adoption more viable (Marks & Thomas, 2022). Simultaneously, improvements in wireless connectivity, processing power, and content development platforms have enhanced VR usability and educational applicability (Elbamby et al., 2018). Chinese universities have begun experimenting with VR across various disciplines, yet the adoption remains fragmented and lacks systematic evaluation. While isolated case studies report positive outcomes, comprehensive evidence regarding VR effectiveness in Chinese online education contexts remains limited, creating a critical need for systematic synthesis of existing research to inform evidence-based implementation strategies (Luo et al., 2021).

Virtual reality (VR) has emerged as a potential response to these challenges by enabling immersive, interactive, three-dimensional learning environments (Pellas et al., 2021). Unlike screen-based instruction, VR allows learners to manipulate virtual objects, explore spatial relationships, and practice real-world skills in safe and repeatable simulations. These affordances directly address key deficiencies of online education namely, the lack of experiential learning, embodied interaction, and authentic practice capabilities that are especially relevant to STEM education, medical training, and architectural design. From a constructivist perspective, VR-enhanced learning environments position students as active participants who construct knowledge through exploration and direct experience rather than passive recipients of information.

The integration of VR into Chinese university online education has become increasingly feasible due to recent technological and economic developments. The cost of VR hardware has declined substantially, improving institutional accessibility, while advances in wireless connectivity, processing power, and content development platforms have enhanced the usability of VR for educational purposes (Huang & Liaw, 2018). Chinese universities have begun experimenting with VR across multiple disciplines. However, adoption remains fragmented and uneven, and empirical findings are dispersed across isolated case studies with inconsistent evaluation criteria. Although many studies report positive outcomes, systematic evidence regarding how VR is implemented, what effects it produces, and under what conditions it is effective in Chinese online higher education remains limited (Llanos-Ruiz et al., 2025).

In this review, VR refers to immersive, interactive three-dimensional digital environments that support experiential learning beyond conventional screen-based instruction. Online education is understood as institutionally organized learning that occurs primarily through networked digital platforms, enabling instruction independent of geographical location (Stracke et al., 2025).

1.2 Purpose and Rationale

Although a growing body of research has examined the use of VR and related immersive technologies in education, existing reviews tend to aggregate studies across heterogeneous contexts, including K-12 and higher education, face-to-face and online instruction, and VR, AR, and mixed-reality applications. Moreover, many syntheses focus on general educational benefits without differentiating cultural, institutional, or infrastructural conditions that may shape implementation and effectiveness.

In the Chinese higher education context, empirical studies have explored VR-supported flipped classrooms, collaborative knowledge construction in augmented or immersive environments and discipline-specific VR applications. However, these studies remain fragmented, employ diverse outcome measures, and rarely distinguish between online and face-to-face instructional settings (Petersen et al., 2023). It remains unclear how VR has been systematically implemented in Chinese university online education, what learning, motivational, and engagement outcomes have been documented, and what pedagogical or contextual factors condition its effectiveness.

Accordingly, there is a critical need for a systematic review that consolidates empirical evidence on VR-based online learning specifically within Chinese universities. Such a synthesis is necessary to clarify the current state of knowledge, reconcile inconsistent findings, and provide a robust empirical foundation for educators, administrators, and policymakers considering large-scale VR adoption.

1.3 Scope

This systematic review synthesizes empirical research on the application of VR in online education at Chinese universities. It aims to (a) map how VR has been implemented across disciplines and instructional designs, (b) examine reported learning, motivational, and engagement outcomes, and (c) identify pedagogical, technological, and contextual factors that moderate its effectiveness.

To address these aims, the review is guided by the following research questions:

(1) How has VR been implemented in online courses at Chinese universities?

(2) What learning, motivational, and engagement outcomes have been reported?

(3) What factors influence the effectiveness of VR in Chinese university online education?

By consolidating findings across multiple studies and disciplinary contexts, this review seeks to provide an evidence-based synthesis of VR-supported online education in Chinese higher education, identify research gaps, and propose directions for future investigation.

2. Method

2.1 Review Protocol and Registration

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, comprehensiveness, and methodological rigor (Page et al., 2021). The review protocol was developed a priori to establish clear procedures for study identification, selection, data extraction, and synthesis. While the protocol was not formally registered in a public database such as PROSPERO, all methodological decisions were documented to maintain transparency and reproducibility.

2.2 Search Strategy

A systematic literature search was conducted in the Web of Science Core Collection database in between January 1, 2015, and March 15, 2025. To supplement the database search and minimize the risk of missing relevant studies, we employed backward citation searching by manually examining the reference lists of all included studies and relevant review articles identified during the screening process. The search strategy was designed to capture studies at the intersection of three core concepts: (1) virtual reality technology, (2) online education contexts, and (3) Chinese higher education settings. Search terms within each concept were combined using the Boolean operator “OR” and the three concept groups were combined using “AND.”

2.3 Eligibility Criteria

Students enrolled in Chinese universities or higher education institutions (including undergraduate, graduate, and professional degree programs) (Zhuang et al., 2024). Use of virtual reality technology as a teaching tool, instructional medium, or learning environment. VR was operationally defined as computer-generated, three-dimensional, interactive digital environments that users can explore and with which they can interact (Huang et al., 2010). This included head-mounted displays (HMDs), desktop-based VR systems, CAVE (Cave Automatic Virtual Environment) systems, and mobile VR applications. Studies could examine VR as the primary intervention or as part of a broader educational technology implementation (Marougkas et al., 2023).

The decision to exclude a study from the final analysis was based on a set of pre-defined criteria designed to maintain the focus and rigor of the review (Page et al., 2021). A study was not considered for inclusion if its scope was limited to K-12 education, corporate training, or professional development contexts outside of higher education. We also excluded research that investigated augmented reality (AR) or mixed reality (MR) without a clearly defined and distinct virtual reality (VR) component, ensuring our focus remained on immersive, VR-driven interventions. Furthermore, studies conducted solely in traditional, in person classroom settings without any online, distance, or blended learning elements fell outside the boundaries of our investigation into technology mediated education. To ground the review in empirical evidence, we omitted no empirical work such as purely conceptual papers, theoretical essays, editorials, book reviews, and systematic reviews that did not present original data. Similarly, articles that only described a technology’s development or architecture without reporting on its actual educational implementation or measurable learning outcomes were set aside. A study was also excluded if its methodological description was insufficient for us to critically evaluate its design or analytical procedures. In cases of duplicate publications, we retained the most comprehensive version to avoid data overlap. Finally, despite our best efforts to obtain all relevant literature, any study that remained unavailable in full-text format was necessarily excluded from the analysis.

2.4 Study Selection Process

The study selection process followed a systematic, multi-stage approach aligned with PRISMA guidelines. It began with the initial database search on March 15, 2025, which identified 312 records. Following the removal of 47 duplicates through EndNote 20 and manual verification, 265 unique records underwent title and abstract screening by two independent reviewers. At this stage, 227 records were excluded, leaving 38 articles for full-text assessment. During the full-text review, the two reviewers independently applied the inclusion and exclusion criteria, resolving disagreements through discussion or, in three cases, by consulting a third reviewer. This resulted in 22 studies being selected for inclusion. The primary reasons for excluding 16 studies at this stage were: a focus on non-VR technologies like AR or MR (n=5), a context outside Chinese universities (n=3), an exclusively face-to-face implementation without online or blended components (n=4), a non-empirical design such as a conceptual paper (n=2), and insufficient methodological detail (n=2). An additional backward citation search of the included studies and relevant reviews yielded 3 further records, one of which met the inclusion criteria after full-text screening. Consequently, the final sample comprised 23 studies. Inter-rater reliability, calculated using Cohen's kappa in SPSS version 28, indicated substantial agreement during title/abstract screening (κ = 0.84) and high agreement during full-text assessment (κ = 0.91). All disagreements were successfully resolved through consensus. The complete flow of this process is detailed in the PRISMA diagram (Figure 1).

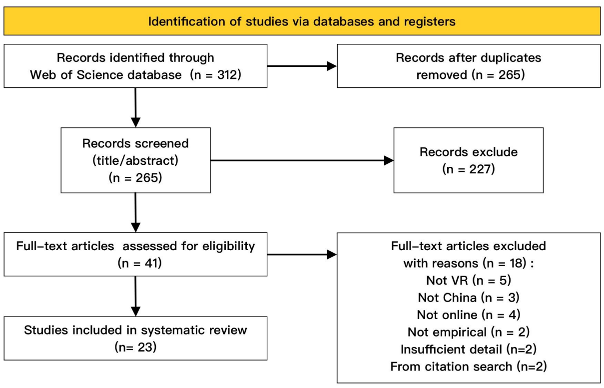

Figure 1. Prisma Flow.

2.5 Data Synthesis and Analysis

A standardized data extraction form was developed for this review and pilot-tested on three studies before two reviewers independently extracted data from all 23 included studies. Any discrepancies were resolved through consensus, and authors were contacted for clarification when necessary. The extracted data encompassed detailed information across ten categories: study identification, research design, participant characteristics, course context, VR intervention details, comparison conditions, outcome measures, main findings, study quality indicators, and author conclusions. To assess methodological rigor, the methodological quality of each study was independently appraised by two reviewers using the Mixed Methods Appraisal Tool (MMAT) 2018. Disagreements in quality ratings were resolved through discussion. Given the substantial heterogeneity in study designs, interventions, and outcome measures across the included literature, a quantitative meta-analysis was deemed inappropriate. Consequently, a structured narrative synthesis was conducted, organized around the three primary research questions. The synthesis process involved preliminary grouping of studies, tabulation of findings, identification of patterns, exploration of heterogeneity, and an assessment of the strength of the evidence, which was categorized as strong, moderate, limited, or insufficient. One planned deviation from the protocol was the execution of the database search exclusively in Web of Science, supplemented by backward citation searching, due to substantial overlap with Scopus. Several methodological limitations of the review are acknowledged, including potential publication bias, the constraint of a single-database and English-language search, the varying quality of primary studies, and the contextual specificity to Chinese universities, all of which were considered when interpreting the synthesized findings.

3. Results

This section presents findings from a systematic review of 23 empirical studies on VR applications in online education at Chinese universities, addressing three primary research questions: (1) How has VR been implemented in online courses? (2) What learning, motivational, and engagement outcomes have been reported? (3) What factors influence VR's effectiveness? The review process resulted in the inclusion of 23 empirical studies published between 2015 and 2025, with 19 (82.6%) appearing in peer-reviewed journals and 4 (17.4%) as full-text conference proceedings. A notable temporal pattern emerged, with 17 studies (73.9%) published between 2020 and 2024, reflecting heightened interest following the COVID-19 pandemic and the rapid expansion of online learning. Geographically, studies were concentrated in Eastern (12 studies, 52.2%) and Northern China (6 studies, 26.1%), with Central and Western regions represented by 5 studies (21.7%), illustrating the uneven distribution of higher education resources and technological infrastructure. Methodologically, quasi-experimental designs (9 studies, 39.1%) and pre-post single-group designs (7 studies, 30.4%) were most common, with only 2 studies employing random assignment. The total sample comprised 2,247 students, with a median sample size of 86 per study, and the majority (18 studies, 78.3%) involved undergraduate participants. Disciplinary applications showed significant concentration, with over half of the studies (12, 52.2%) in STEM fields, followed by health sciences (5 studies, 21.7%) and architecture/design (3 studies, 13.0%), indicating VR's particular relevance for disciplines requiring spatial reasoning, procedural skills, or three-dimensional visualization. Table 1 provides detailed characteristics of all included studies.

The methodological quality assessment of the 23 included studies using the MMAT revealed considerable variation: eight studies (34.8%) were rated as high quality, meeting all or nearly all criteria; eleven studies (47.8%) were rated as moderate quality; and four studies (17.4%) were rated as lower quality. When analyzed by study design, quasi-experimental studies (nine studies) demonstrated relatively standardized measurement and implementation but commonly exhibited inadequate control of confounding variables, limited sample representativeness, and insufficient handling of attrition. Single-group pre-post studies (seven studies) presented complete data but lacked control groups, making it difficult to attribute effects specifically to VR. Mixed-methods studies (five studies) showed room for improvement in methodological integration and consistency between components. The two qualitative studies performed adequately in terms of methodological appropriateness. Several common methodological issues were identified across the studies, including insufficient sample sizes, use of unvalidated instruments, inadequate control of key confounding variables, short intervention durations, and overreliance on self-reported data. Despite these limitations, none of the studies were excluded based on quality ratings; however, in the subsequent synthesis and discussion, greater emphasis will be placed on consistent evidence from higher-quality studies for careful interpretation.

4. Discussion

The systematic review consistently demonstrates that VR-enhanced online learning yields significant advantages in knowledge, skills, and conceptual understanding compared to traditional online methods, with comparative studies showing medium-to-large effect sizes (median Cohen's *d* = 0.72). This efficacy is underpinned by constructivist and experiential learning mechanisms, including active knowledge construction, multimodal processing, embodied learning, and the contextual embedding of content, with benefits observed for spatial and procedural learning. However, important nuances emerged. While VR robustly enhances engagement and motivation, longitudinal data reveal an initial novelty peak followed by a gradual decline, suggesting it should be deployed strategically, not ubiquitously. Furthermore, the higher presence in HMDs does not automatically guarantee superior learning outcomes and correlates only moderately with achievement, indicating that instructional design is a more critical factor than hardware alone. The most consistent moderator of effectiveness was the quality of instructional design, encompassing balanced scaffolding, meaningful interactivity, structured post-experience reflection, and clear alignment between VR activities and learning objectives. These findings showed that VR’s educational value is not inherent in the technology but is realized through its thoughtful integration within a sound pedagogical framework. However, the successful transition from “technological affordance” to “pedagogical reality” is contingent upon the instructor’s Technological Pedagogical Content Knowledge (TPACK). Evidence suggests that the primary barrier to VR integration in Chinese universities is not merely a lack of hardware, but a structural imbalance in teachers' TPACK. While many educators possess sufficient Content Knowledge (CK) and basic Technological Knowledge (TK), they often struggle with the intersection of the two Technological Pedagogical Knowledge (TPK). This manifest as a difficulty in aligning VR’s immersive capabilities with specific instructional strategies, such as inquiry-based or collaborative learning. Without a sophisticated understanding of how to transform complex disciplinary content into immersive experiences (TCK), teachers risk using VR as a high end “demonstration tool” rather than a vehicle for deep constructivist interaction. Moreover, managing student cognitive load and potential cyber-sickness during VR sessions requires specialized pedagogical monitoring, further highlighting that active instructor facilitation underpinned by a holistic TPACK framework remains essential.

5. Future Research Directions

Based on this systematic review, several critical directions for future research emerge to advance the field beyond exploratory pilots. Methodologically, priority must be given to conducting rigorous Randomized Controlled Trials (RCTs) with active control conditions to isolate VR-specific effects from general active learning benefits, alongside longitudinal studies assessing the long-term retention of learning and the sustainability of engagement beyond initial novelty. Comprehensive cost-effectiveness analyses are urgently needed to inform institutional decision-making. Substantively, key questions center on understanding individual differences such as spatial ability, prior knowledge, and personality traits that moderate VR’s effectiveness to enable personalized learning, and on establishing evidence-based instructional design principles for optimal scaffolding, feedback, and collaboration within VR environments. Research must also expand into underrepresented disciplines like the humanities and social sciences, and rigorously investigate the transfer of VR-acquired skills to real-world contexts. Emerging areas warranting exploration include the integration of Artificial Intelligence for adaptive tutoring, the development of social VR platforms to mitigate online isolation, and dedicated studies on accessibility and universal design to ensure equitable implementation. Furthermore, cross-cultural comparative research is essential to evaluate the generalizability of findings beyond the Chinese context, and implementation science is needed to understand pathways for sustainable, large-scale adoption. To consolidate knowledge, the field should adopt open science practices and develop standardized measurement instruments. Future efforts should be theoretically driven and interdisciplinary, prioritizing foundational questions of effectiveness, individualization, and cost to translate promising innovation into evidence-based practice.

6. Conclusion

This systematic review analyzes the application of Virtual Reality (VR) technology in online higher education within Chinese universities between 2015 and 2025. The findings indicate that VR serves as a key tool for addressing critical challenges in online education, such as lack of interactivity, low engagement, and insufficient experiential learning opportunities (Asad et al., 2021). Compared to traditional screen-based instruction, VR demonstrates significant positive effects, leading to enhanced student motivation, knowledge retention, and practical skills acquisition, with effect sizes ranging from moderate to large.

The review reveals that VR's effectiveness is most pronounced in disciplines emphasizing spatial reasoning, including STEM fields, medical education, and architectural design. A core conclusion is that the pedagogical value of VR is not determined by hardware alone; rather, the quality of instructional design particularly constructs grounded in constructivist principles, such as scaffolded design, interactive elements, and structured post experience reflection emerges as the critical moderating variable influencing learning outcomes. Furthermore, the potential decline in engagement due to the “novelty effect” warrants caution, positioning VR as a strategic pedagogical supplement rather than a wholesale replacement for traditional methods.

Despite its promising potential, widespread integration in Chinese higher education faces major obstacles, including uneven infrastructure distribution, high costs, and insufficient instructor training. Future research should employ rigorous Randomized Controlled Trials (RCTs) to validate VR's long-term efficacy and investigate the impact of individual learner differences on outcomes. In summary, VR is transitioning from a technological pilot to a mainstream educational solution. To achieve sustainable educational empowerment, institutions must shift their focus from mere technology deployment to a deeper, pedagogy centric integration.

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