

Review

Current Status, Problems, and Countermeasures of the Application of Virtual Reality (VR) Technology in Higher Education Teaching

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Abstract: Virtual reality technology has emerged as a transformative force in higher education, promising immersive, experiential, and learner-centered pedagogical models. This review synthesizes the current landscape of VR integration across universities worldwide, identifying persistent gaps between technological capability and educational implementation. While early adoption demonstrates measurable gains in student engagement, knowledge retention, and skill acquisition---particularly in STEM, medicine, and design disciplines---systemic barriers remain deeply entrenched. These include infrastructural limitations, faculty readiness deficits, pedagogical misalignment, assessment ambiguities, and ethical concerns surrounding data privacy and cognitive load. Drawing on cross-institutional patterns and longitudinal implementation reports, this paper organizes evidence around two interlocking thematic axes: the evolving affordances of VR hardware-software ecosystems in academic contexts, and the institutional, curricular, and human factors that mediate or obstruct their effective deployment. We argue that sustainable advancement hinges not on technological escalation alone, but on co-designed frameworks that prioritize pedagogical integrity, equity of access, and iterative educator-led development. The review concludes with actionable pathways for policy, practice, and research aimed at transitioning VR from episodic novelty to embedded educational infrastructure.

Keywords: virtual reality; higher education; educational technology

1. Introduction

1.1. The Pedagogical Imperative for Immersive Learning

Contemporary higher education faces mounting pressure to cultivate experiential competencies---particularly in domains requiring spatial reasoning, procedural mastery, or risk-averse practice. Traditional pedagogical models increasingly falter when confronting complex, dynamic, or hazardous subject matter, where passive reception proves insufficient for deep conceptual integration [1]. Learners now expect active, contextualized engagement that mirrors real-world application, yet institutional infrastructures often remain anchored in lecture-centric delivery [2, 3]. This misalignment intensifies challenges in disciplines such as medicine, engineering, and environmental science, where abstract knowledge must translate into embodied judgment and adaptive decision-making. Immersive learning paradigms thus emerge not as technological novelties but as pedagogical necessities---capable of bridging epistemic gaps between theory and situated practice while scaffolding cognitive load through multimodal representation and interactive feedback loops [2, 4].

1.2. Scope and Purpose of This Review

This review focuses exclusively on the integration of virtual reality technology within degree-granting higher education institutions, deliberately excluding K--12 settings, corporate training programs, and broader edtech market trends [5]. Its primary objectives

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are threefold: first, to systematically map current pedagogical applications of VR across disciplines and institutional contexts; second, to diagnose persistent structural impediments—including infrastructural limitations, faculty development gaps, curricular misalignment, and assessment challenges; and third, to propose empirically grounded, institutionally scalable countermeasures that bridge technological capability with educational efficacy [1, 6]. The analysis prioritizes actionable insights over descriptive enumeration, emphasizing coherence between technical implementation and learning outcomes.

1.3. Methodological Orientation

This review adopts a dual-axis conceptual architecture that interrogates VR integration along two interdependent dimensions: technological affordances and human-institutional mediation [2, 7]. Rather than pursuing systematic bibliometric enumeration, the analysis follows a rigorously thematic synthesis approach, prioritizing implementation fidelity—how VR tools are enacted in pedagogical practice—over granular technical specifications [2, 8]. Emphasis is placed on contextualized usage patterns, instructor agency, curricular alignment, and institutional support structures. The framework deliberately foregrounds socio-technical contingencies, recognizing that educational outcomes depend less on hardware capabilities than on mediated adoption pathways [7, 9]. This orientation enables nuanced identification of structural enablers and constraints across diverse academic settings, supporting actionable, context-sensitive countermeasure development rather than generic technological prescription [6, 10].

2. Historical Overview: From Simulation Labs to Classroom Integration

2.1. Foundational Developments in Academic VR

The evolution of academic virtual reality infrastructure reflects a deliberate trajectory from specialized research instrumentation toward pedagogical scalability [6, 11]. The timeline begins with CAVE systems deployed between 1992 and 1999, confined to physics and engineering departments and demanding dedicated physical spaces and advanced technical oversight [12]. The subsequent decade saw medical simulation suites emerge, integrating task-specific haptics and standardized clinical protocols aligned with professional accreditation frameworks [1, 3]. Engineering visualization clusters followed from 2010 to 2015, enabling collaborative CAD walkthroughs via multi-display stereoscopic workbenches [3]. Consumer headset pilots between 2016 and 2020 introduced Oculus Rift and HTC Vive into undergraduate laboratories, though constrained by hardware bottlenecks and inherently solitary interaction models. Most recently, classroom-ready ecosystems have materialized from 2021 to 2024, characterized by standalone headsets managed through enterprise dashboards, shared device cart logistics, and seamless learning management system integration for activity tracking. This progression underscores a systemic shift—from isolated, discipline-bound immersion toward institutionally supported, pedagogically embedded, and logistically sustainable deployment models.

2.2. The Consumer Hardware Inflection Point

The consumer hardware inflection point, commencing around 2016, fundamentally reconfigured VR's pedagogical accessibility. Mass-market headsets—priced below USD 400—dramatically reduced institutional acquisition costs, enabling pilot deployments across diverse higher education settings, not solely resource-rich research universities. Concurrent advances in inside-out tracking eliminated external sensor dependencies, simplifying classroom setup and improving spatial fidelity for immersive simulations [8, 12]. Authoring platforms evolved from proprietary, code-intensive environments to drag-and-drop interfaces with prebuilt educational templates, lowering technical thresholds for faculty without programming expertise. This convergence of affordability, robustness, and usability catalyzed discipline-specific adoption: medical programs leveraged anatomical visualization; engineering departments deployed virtual prototyping labs;

and humanities courses integrated spatial narrative environments [11]. Crucially, the shift moved VR beyond isolated simulation labs toward scalable, curriculum-embedded applications. However, uneven infrastructure readiness, variable faculty digital literacy, and persistent interoperability constraints across learning management systems continue to moderate diffusion velocity. The inflection point thus marks not a completed transition but a foundational acceleration phase—one wherein hardware democratization preceded corresponding pedagogical standardization and institutional support frameworks.

2.3. Pedagogical Evolution Alongside Technology

The pedagogical evolution accompanying VR adoption reflects a decisive shift from behaviorist transmission models toward constructivist and embodied cognition paradigms. Early VR applications emphasized passive demonstration—visualizing abstract concepts through static simulations—aligning with objectivist epistemologies. As learning theory advanced, design priorities recalibrated to prioritize learner agency, situated practice, and multimodal sense-making. Constructivist principles drove the integration of open-ended exploration, scaffolded problem-solving, and reflective metacognitive prompts within VR environments [4]. Concurrently, embodied cognition frameworks prompted deliberate incorporation of gesture-based interaction, spatial navigation, and sensorimotor feedback loops, reinforcing knowledge as grounded in physical experience rather than disembodied abstraction [7, 8]. These theoretical commitments transformed VR from a novelty-driven visualization tool into a medium for collaborative inquiry, peer-mediated co-construction of meaning, and iterative reflection-in-action. Consequently, instructional design increasingly foregrounds activity structures that demand negotiation of shared virtual spaces, real-time adaptation to dynamic scenarios, and articulation of emergent understanding—features now considered essential rather than peripheral to effective implementation. This convergence of theory and technology has redefined fidelity criteria: not merely visual realism, but epistemic authenticity, cognitive engagement depth, and social affordance richness [3, 5].

3. Core Theme A: Technological Affordances and Educational Realities

3.1. Hardware Maturation and Contextual Constraints

The relationship between headset hardware attributes and classroom deployment viability reveals systemic trade-offs that constrain pedagogical scalability. Resolution and visual fidelity directly impact text legibility below 10px thresholds, necessitating fixed gaze anchors paired with audio narration to sustain cognitive load management during extended reading tasks [7]. Field of view limitations induce peripheral occlusion, undermining collaborative spatial reasoning; depth cue mismatches further exacerbate disorientation, mitigated through pre-session spatial priming and tactile floor markers to recalibrate embodied orientation. Comfort constraints manifest as thermal buildup exceeding fifteen minutes and inter-pupillary distance adjustment failure for approximately twelve percent of users—addressed via rotating eight-minute station rotations and modular nose pads calibrated across anthropometric quartiles. Mobility and shared logistics present acute infrastructural challenges: cable entanglement impedes fluid movement in multi-user labs, while battery decay introduces performance variance across sequential task groups. Wireless mesh charging carts coupled with time-stamped usage logs enable equitable device allocation and longitudinal performance normalization [2]. Collectively, these constraints demonstrate that hardware maturation alone does not guarantee educational integration; rather, viability emerges from tightly coupled affordance-mitigation pairings mapped to specific instructional activities [7]. The taxonomy underscores that resolution deficits are not merely optical but epistemic—compromising information access equity—while field-of-view restrictions transform spatial cognition from a distributed group process into an isolated perceptual bottleneck [2, 3]. Session duration limits expose physiological thresholds that override technological capability, demanding temporal scaffolding aligned with attentional rhythms rather than computational throughput. Shared logistics failures reflect infrastructural misalignment,

where device-centric design neglects classroom-scale coordination protocols. Thus, classroom deployment viability is not a function of peak specifications but of context-sensitive calibration across four interdependent domains.

3.2. Software Ecosystems and Curriculum Alignment

The academic VR software ecosystem exhibits pronounced heterogeneity in curricular alignment capacity, as detailed in Table 1. Proprietary discipline-specific platforms, such as Osso Surgery, enforce rigid procedural scripts that resist remapping to alternative learning outcomes, thereby constraining epistemic flexibility across pedagogical paradigms. In contrast, open-source authoring environments like Unity combined with WebXR afford full scene logic editing but impose steep coding literacy requirements, limiting instructor agency over scaffolding design without technical support infrastructure. LMS-integrated SaaS solutions, exemplified by Engage EDU, prioritize usability through drag-and-drop activity sequencing and pre-built rubric templates, yet may sacrifice disciplinary nuance for standardization. Assessment integration further stratifies platform utility: proprietary systems deliver only post-session skill scores without formative feedback triggers; open-source tools enable custom event logging but necessitate manual analytics pipelines incompatible with institutional data governance protocols; while integrated SaaS platforms auto-sync performance metrics to gradebooks and embed peer-review workflows alongside reflection prompts. This tripartite divergence reveals a structural misalignment between technological affordances and pedagogical sovereignty---particularly regarding instructor control over sequencing fidelity, adaptability to domain-specific epistemologies (e.g., iterative hypothesis testing in science versus narrative coherence in humanities), and seamless compatibility with existing assessment architectures [12]. Consequently, curriculum integration remains contingent not on technical capability alone but on the degree to which platform design acknowledges pedagogical intentionality as a first-order constraint rather than an afterthought [5]. Without deliberate architectural mediation between software logic and instructional design theory, VR risks reinforcing mechanistic transmission models rather than enabling constructivist, outcome-responsive teaching practices [11].

Table 1. Comparative Analysis of Academic VR Software Platforms

Platform Type	Curricular Adaptability	Assessment Integration
Proprietary Discipline-Specific (e.g., Osso Surgery)	Fixed procedural scripts; no outcome re-mapping	Post-session skill scores only; no formative triggers
Open-Source Authoring (e.g., Unity + WebXR)	Full scene logic editing; requires coding literacy	Custom event logging; requires manual analytics pipeline
LMS-Integrated SaaS (e.g., Engage EDU)	Drag-and-drop activity sequencing; pre-built rubric templates	Auto-synced to gradebook; supports peer-review workflows and reflection prompts

3.3. Data Infrastructure and Technical Support Capacity

As illustrated in Figure 1, the Institutional Infrastructure Readiness Matrix reveals a stratified landscape of technical capacity across higher education institutions, structured along two orthogonal axes: Technical Maintenance Capacity and Network & Backend Scalability. The Sustained Ecosystem Tier---occupying the top-right quadrant---represents institutions where device refresh cycles fall below twenty-four months, dedicated VR DevOps teams operate continuously, and edge routing infrastructure supports 10Gbps throughput. Such environments enable scalable multi-user simulations with real-time analytics, reflecting systemic integration rather than isolated experimentation. In contrast, the Bandwidth-Constrained Innovation Tier (top-left) features high-speed fiber access limited to specialized laboratories and absent centralized provisioning protocols; this configuration sustains only single-session synchronous labs reliant on local caching

mechanisms. The Maintenance-Rich Fragmentation Tier (bottom-right) demonstrates robust firmware-level IT staff competency but lacks network modernization, resulting in isolated departmental deployments requiring manual synchronization—a condition that impedes cross-unit pedagogical coherence [6]. Finally, the Baseline-Compliant Tier (bottom-left) exhibits partial Wi-Fi 6 coverage—reaching approximately sixty percent of classrooms—and no VR-dedicated personnel, constraining implementation to Bring-your-Own-Device lightweight webXR activities. This matrix underscores that infrastructural readiness is not unidimensional: high maintenance capacity without scalable networking yields fragmentation, while strong bandwidth without sustained device lifecycle management introduces obsolescence risks [8]. Consequently, institutional investment strategies must align hardware renewal schedules, network architecture upgrades, and staff upskilling pathways in concert—not sequentially—to avoid misalignment between technical thresholds and educational delivery fidelity. Without such coordinated advancement, VR adoption remains tethered to episodic demonstration rather than embedded instructional practice.

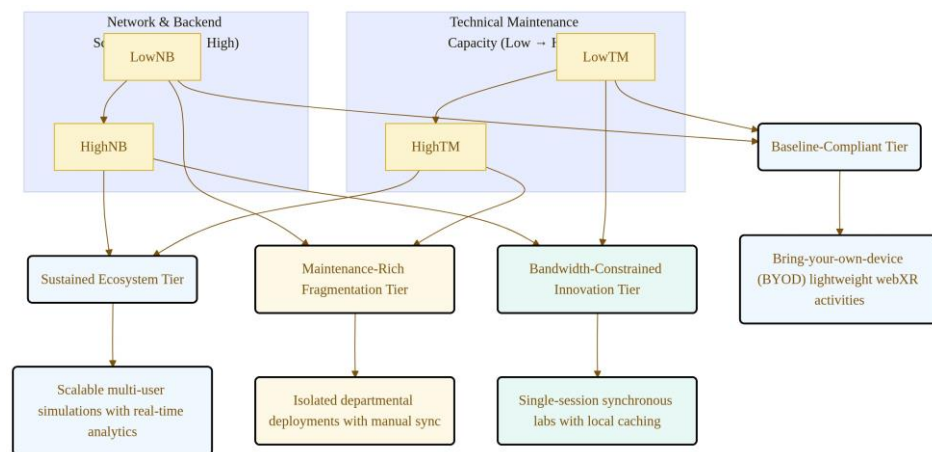


Figure 1. Institutional Infrastructure Readiness Matrix

4. Core Theme B: Human and Institutional Mediation

4.1. Faculty Readiness and Professional Development

Faculty readiness for VR integration in higher education teaching operates along a hierarchical competency continuum. Stage 1: Tool Fluency establishes the indispensable technical foundation—headset calibration, basic navigation commands, and content loading workflow—without which subsequent pedagogical engagement remains infeasible [8]. Stage 2: Scenario Design Literacy builds upon this base, requiring instructors to align VR tasks with Bloom's taxonomy verbs, embed reflection prompts at critical decision points, and design for multiple modalities including audio and tactile fallbacks to ensure accessibility and cognitive redundancy [6]. Stage 3: Facilitation Mastery represents the apex of professional development, demanding the capacity to manage disengagement during immersion, debrief embodied experiences without reducing them to abstraction, and adapt pacing based on biometric cues when available [8, 12]. Crucially, this cumulative dependency structure reveals a common misalignment in institutional support: many professional development programs frequently misallocate resources by prioritizing Stage 1 tool training while neglecting the scaffolded progression required for design literacy and facilitation mastery. This imbalance results in technically competent but pedagogically underprepared instructors who deploy VR as a novelty rather than a transformative learning medium. Effective support systems must therefore adopt a tiered delivery model, sequencing workshops, peer mentoring, and reflective practice cycles across all three stages. Moreover, assessment mechanisms should evaluate not only procedural accuracy but also instructional intentionality—measuring how well VR activities instantiate disciplinary epistemologies and foster metacognitive awareness.

Without such structural alignment between faculty development architecture and the competency pathway, VR adoption risks entrenching inequitable access, superficial implementation, and diminished learning returns [8].

4.2. Curricular Integration Beyond the Pilot

Sustained curricular integration of VR technology demands resolution of structural tensions between pedagogical innovation and academic governance. Course redesign timelines frequently exceed standard semester planning cycles, while credit-hour allocation pressures constrain faculty capacity to develop immersive learning modules without commensurate workload adjustments [6]. Assessment frameworks remain misaligned with VR's experiential affordances, as conventional rubrics struggle to capture spatial reasoning, embodied interaction, or collaborative presence [2]. Syllabus standardization further complicates adoption, since discipline-specific learning outcomes resist uniform VR implementation protocols. Departmental ownership models thus become decisive mediators of scalability [7, 10]. As detailed in Table 2, the VR Governance Architecture Comparison reveals three distinct institutional pathways. Department-Led Incubation anchors VR development within disciplinary autonomy, linking infrastructure investment and curriculum control to tenure and promotion criteria specific to each field. Centralized Pedagogy Units operate as university-funded entities that mandate faculty fellowships, embedding VR competence into teaching excellence awards and protected release time. Cross-College Consortia distribute responsibility across academic units via shared infrastructure funds and rotating steering committees, tying sustainability to interdepartmental alignment on learning outcome metrics. Each model presents trade-offs: decentralized approaches accelerate context-sensitive innovation but risk fragmentation and quality variance; centralized structures enforce consistency and technical rigor yet may suppress disciplinary nuance; consortium models foster cross-pollination but require sustained administrative coordination and outcome harmonization [6]. None fully resolves the tension between localized pedagogical agency and system-wide quality assurance. Successful scaling therefore hinges not on selecting a single architecture, but on calibrating governance levers---budgetary authority, faculty incentives, assessment mandates, and syllabus flexibility---to match institutional priorities, disciplinary epistemologies, and student learning ecologies. Without such calibration, VR remains confined to isolated pilots rather than integrated curricular infrastructure.

Table 2. Institutional Governance Models for VR Integration

Model Type	Ownership Structure	Sustainability Mechanism
Department-Led Incubation	Discipline-specific budget + curriculum autonomy	Tied to tenure/promotion metrics in discipline
Centralized Pedagogy Unit	University-funded unit with mandated faculty fellowships	Embedded in teaching excellence awards and release time
Cross-College Consortium	Shared infrastructure fund + rotating steering committee	Tied to interdepartmental learning outcome alignment mandates

4.3. Equity, Access, and Ethical Considerations

The Three-Dimensional Equity Framework for Immersive Learning reveals that access, embodiment, and agency operate not as isolated dimensions but as interlocking structural axes shaping VR's pedagogical legitimacy. Access Equity exposes infrastructural stratification: device availability diverges sharply across income brackets, while urban campuses routinely deploy high-fidelity headsets absent from rural or satellite institutions, and disability accommodation remains superficial---vestibular-safe locomotion modes are rarely implemented despite documented motion-sickness disparities [1]. Embodiment Equity interrogates representational fidelity: avatar customization often lacks granular skin-tone palettes, gender-expression options, or integrated mobility aids; scenario design frequently defaults to Western clinical protocols

or Eurocentric spatial logics, marginalizing indigenous epistemologies and non-dominant cultural norms; biometric consent mechanisms remain monolithic rather than enabling opt-in per metric---gaze tracking, heart-rate variability, and voice-stress analysis each demand distinct ethical thresholds. Agency Equity challenges pedagogical sovereignty: learners seldom possess meaningful control over narrative branching or real-time co-creation tools within VR environments, and opt-out pathways---when available---are structurally punitive, requiring alternative assignments that carry implicit stigma and credit dilution [6, 11]. Critically, these dimensions intersect: limited device access constrains embodiment choices, which in turn diminishes agentic participation; conversely, robust agency frameworks cannot compensate for foundational inequities in access or embodied representation. Institutional mediation thus requires coordinated policy intervention---not merely procurement upgrades or interface tweaks---but systemic recalibration across technological infrastructure, curriculum design, and data governance architectures to ensure VR serves as an equity amplifier rather than a disparity accelerator.

5. Comparison & Challenges: Cross-Disciplinary Patterns and Persistent Tensions

5.1. Disciplinary Variations in Adoption Trajectories

Disciplinary adoption trajectories of virtual reality in higher education reveal pronounced heterogeneity in implementation depth and pedagogical rationale [11]. In health sciences, VR deployment emphasizes high-fidelity procedural simulation---surgical rehearsal, anatomical dissection, and clinical decision-making---where fidelity directly correlates with skill transfer and patient safety outcomes [3]. Architecture and design disciplines prioritize spatial cognition, leveraging immersive 3D modeling to enhance perception of scale, materiality, and environmental context, thereby bridging conceptual abstraction and built reality. By contrast, social sciences deploy VR primarily for collaborative, scenario-based problem-solving: ethical dilemmas, cross-cultural negotiation, or historical reenactment, where the medium's strength lies in embodied perspective-taking rather than technical replication. These divergent emphases reflect underlying epistemological commitments---embodied competence in clinical training, perceptual calibration in design, and intersubjective understanding in humanistic inquiry. Consequently, institutional support mechanisms, faculty development priorities, and assessment frameworks remain fragmented across domains. Standardized evaluation metrics fail to capture discipline-specific learning affordances, while infrastructure investments often privilege technologically intensive applications over scalable, pedagogically grounded integration. Such asymmetries impede cross-disciplinary knowledge transfer and sustain persistent tensions between innovation rhetoric and curricular coherence.

5.2. The Implementation Chasm

The implementation chasm manifests as a tripartite structural misalignment across higher education institutions adopting virtual reality [5]. First, substantial capital investment in VR hardware and software rarely translates into sustained pedagogical infrastructure---faculty development, curriculum integration frameworks, and technical support ecosystems remain underfunded and fragmented. Second, while student engagement metrics often show initial enthusiasm, longitudinal assessments reveal inconsistent correlations between VR exposure and demonstrable improvements in conceptual retention, critical thinking transfer, or skill mastery across disciplines. Third, although proof-of-concept deployments succeed in controlled environments, operational scalability falters due to interoperability constraints, bandwidth limitations, device management overhead, and lack of standardized assessment protocols [6]. These tensions are not merely logistical but epistemological: they reflect divergent institutional priorities, disciplinary epistemic cultures, and competing conceptions of educational quality. Bridging this chasm requires coordinated policy intervention---not only in resource allocation but in redefining success metrics, incentivizing cross-departmental

collaboration, and embedding iterative design principles into VR adoption lifecycles. Without such systemic recalibration, VR risks entrenching rather than resolving existing pedagogical inequities.

5.3. Misaligned Incentives and Evaluation Gaps

Structural disincentives significantly impede the institutional adoption of VR in higher education [2]. Tenure and promotion frameworks overwhelmingly privilege research output over pedagogical innovation, rendering sustained investment in immersive teaching design professionally unrewarding for faculty. Concurrently, no consensus exists on metrics capable of capturing the multidimensional learning outcomes enabled by VR---such as spatial reasoning, embodied cognition, or affective engagement---leaving efficacy assessments fragmented and methodologically inconsistent [3]. Curriculum development remains largely decoupled from student experience data; feedback loops are infrequent, unstructured, and rarely integrated into iterative design cycles. This absence of systematic linkage between learner interaction patterns, cognitive load indicators, and instructional redesign perpetuates a cycle of ad hoc implementation rather than evidence-informed evolution. Administrative support structures seldom allocate dedicated time, technical staffing, or developmental funding to sustain VR integration beyond pilot phases. Without recalibrating incentive architectures---through revised promotion criteria, discipline-agnostic evaluation rubrics, and embedded instructional design partnerships---the deployment of VR risks remaining episodic, technocentric, and pedagogically underleveraged. Addressing these misalignments demands coordinated policy intervention across academic governance, faculty development, and learning analytics infrastructures.

6. Future Perspectives: Toward Embedded, Equitable, and Pedagogically Grounded VR

6.1. Policy and Governance Pathways

Institutional leadership must prioritize structural integration of VR pedagogy through dedicated academic units that bridge instructional design, technical development, and disciplinary expertise. Cross-departmental consortia should formalize shared infrastructure, licensing, and maintenance protocols to mitigate fragmentation and duplication. Procurement frameworks require explicit inclusion criteria---such as multilingual support, screen reader compatibility, and adjustable cognitive load---to ensure equitable access across diverse learner profiles. Ethics review boards must expand scope to address immersive-specific concerns: biometric data handling, spatial presence effects, and long-term psychological impacts. Governance mechanisms should mandate iterative evaluation cycles tied to learning outcome metrics rather than technological novelty. Policy coherence demands alignment with national digital education strategies while preserving institutional autonomy in curricular adaptation. Sustainable scaling necessitates budgetary line items for faculty VR literacy development and longitudinal impact assessment.

6.2. Design Principles for Sustainable Integration

Sustainable VR integration demands human-centered design cycles that actively engage educators and students from conceptualization through iterative refinement. Modular content architectures enable scalable adaptation across disciplines and institutional infrastructures, while low-bandwidth fallback options ensure accessibility in resource-constrained environments. Built-in analytics must align with learning science principles---tracking engagement, cognitive load, and knowledge retention---not merely usage metrics. Interoperability standards facilitate seamless integration with existing learning management systems and assessment frameworks. Long-term viability requires transparent data governance, energy-efficient hardware deployment, and continuous professional development aligned with pedagogical evolution. Institutional support structures---including dedicated instructional designers, technical maintenance protocols,

and cross-departmental coordination---must be codified into strategic planning. Ultimately, sustainability hinges not on technological novelty but on consistent alignment with educational equity, cognitive validity, and operational resilience across diverse academic contexts.

6.3. Research Priorities for Evidence-Based Advancement

Future research must prioritize longitudinal investigations into knowledge transfer durability across VR-enhanced curricula, rigorously comparing learning outcomes against traditional and hybrid modalities. Cost-benefit analyses of institutional infrastructure investment---spanning hardware procurement, maintenance, faculty development, and technical support---require standardized metrics to inform scalable adoption. Participatory action research, co-designed and led by teaching faculty, is essential to align VR integration with authentic pedagogical workflows and disciplinary epistemologies. Studies should systematically examine equity dimensions, including accessibility for learners with diverse sensory, cognitive, and socioeconomic profiles. Methodological innovation is needed to capture nuanced affective, behavioral, and metacognitive dimensions of immersive learning. Cross-institutional collaboration will strengthen generalizability while preserving contextual fidelity. Empirical validation must move beyond engagement metrics toward demonstrable improvements in conceptual mastery, skill acquisition, and long-term retention.

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