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Unlocking the potential of immersive technologies in higher education: A systematic review

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Abstract

A wealth of literature confirms the benefits of immersive technologies in higher education; however, a critical barrier to scalable adoption remains the lack of comprehensive pedagogical frameworks and institutional support structures. This systematic review synthesizes not only learning outcomes but, more importantly, the instructional strategies and implementation challenges reported across thirty studies (2020–2025). Our analysis identifies a shift toward experiential and collaborative learning models, while highlighting a persistent deficit in formalized training and support for faculty. We argue that the primary challenge is no longer technological but pedagogical. The review's contribution is a set of evidence-based principles for faculty development and pedagogical guidelines tailored to immersive learning, an essential step for sustainable integration.

Keywords: Augmented reality, Higher education, Immersive technologies, Mixed reality, Student engagement, Virtual reality.

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1. Introduction

The integration of immersive technologies represents a significant and transformative evolution in higher education pedagogical approaches. These technologies, collectively termed Extended Reality [1, 2] create environments that variously merge the real and virtual worlds, thereby offering enhanced interactive and engaging learning experiences [3-6]. Extended Reality encompasses Virtual Reality, which provides a fully immersive digital environment, typically through a head-mounted display, isolating the user from the physical world. VR is employed for intricate simulations, such as surgical training or historical reconstructions [7, 8]. Augmented Reality overlays digital information or objects onto the physical environment, enabling users to perceive both real and virtual elements concurrently, often via mobile devices or smart glasses. AR enriches real-world settings with virtual imagery, facilitating the visualization of 3D models [7, 8]. Mixed Reality blends real and virtual spaces, allowing for real-time interaction between physical and digital objects [9]. MR facilitates highly adaptable experiences where physical and virtual components coexist and interact seamlessly [10]. Collectively, these technologies redefine educational paradigms by offering rich, interactive learning environments that surmount the limitations of traditional methods, improving immersion, particularly in fields like hospitality, medicine, and scientific studies [4].

These technologies are increasingly recognized for their capacity to foster deeper comprehension, elevate student engagement, and cultivate essential skill development, surpassing conventional instructional methods [11-15]. The deployment of VR and AR in university settings has consistently shown promise in enhancing student outcomes, improving retention rates, and aiding in the visualization of complex concepts [16-20]. Moreover, immersive technologies are instrumental in nurturing critical 21st-century competencies such as spatial reasoning, problem-solving, creativity, innovation, and the acquisition of practical skills across a wide spectrum of disciplines, especially those that are challenging to replicate in conventional settings [21-24].

However, a comprehensive understanding of their full impact remains elusive. Prior systematic reviews offer valuable insights but are often limited by a narrow focus on single technologies rather than the entire XR spectrum, methodological inconsistencies that impede generalizable conclusions, and an overemphasis on short-term outcomes, leaving the long-term effects on knowledge retention and academic progression underexplored [25-29]. The rapid advancement of these technologies, accelerated by the global transition to hybrid learning models post-2020, necessitates a current and comprehensive synthesis that addresses these specific lacunae.

Consequently, this systematic review endeavors to synthesize and critically evaluate contemporary research published between 2020 and 2025 to meticulously assess the educational outcomes and technological integration of immersive technologies in higher education. By adopting a rigorous and broad-scoped methodology, this review aims to provide a clearer perspective on the field's current status by incorporating the full spectrum of immersive technologies, applying a consistent, rigorous framework for outcome evaluation, and synthesizing evidence for both immediate and potential long-term impacts. Ultimately, this work seeks to identify key findings across diverse disciplines, highlight effective pedagogical strategies, and delineate emerging areas for future research.

This systematic review is guided by the following research questions:

i. What academic disciplines and topics have been taught using immersive technologies in higher education between 2020 and 2025?
ii. What instructional approaches are most commonly and effectively used alongside immersive technologies in this timeframe?
iii. What is the impact of immersive technologies on student learning outcomes in higher education from 2020 to 2025?

1.1. Limitations of previous systematic reviews on Immersive Technologies in Higher Education

While the body of systematic reviews on immersive technologies in higher education has expanded significantly, providing valuable insights into this rapidly evolving field, several limitations and gaps persist in the existing literature. These shortcomings highlight the need for more rigorous, comprehensive, and methodologically sound reviews to fully understand the impact and integration of these technologies.

One significant limitation concerns the scope and breadth of many prior reviews. Some studies have focused narrowly, for instance, exclusively on Virtual Reality without adequately addressing mixed reality or extended reality, thereby reducing the spectrum of technologies analyzed and potentially limiting a complete understanding of their integrative benefits [24]. Similarly, a narrow focus on specific disciplines or the exclusion of pertinent research from conference proceedings and alternative academic forums can further restrict international insights and overlook critical developments [16]. Comprehensive reviews incorporating immersive technologies beyond VR remain scarce, often lacking a holistic mapping of overarching trends and emerging research fronts that shape the digital educational ecosystem [30].

Methodological inconsistencies and challenges represent another critical area of concern. The subjectivity inherent in defining search terms and selection criteria can lead to the exclusion of relevant articles, and restrictions to a limited number of databases can further constrain the identification of studies [31]. Synthesizing the effectiveness of immersive technology in education is challenging due to the variability in technology [32] application, available infrastructure, and educators' judgments [25]. Furthermore, some comparative studies on immersive technologies have been criticized for lacking sufficient control over instructional methods and content, making it difficult to definitively attribute learning outcomes to the immersive media itself rather than other pedagogical factors [33]. Prior reviews also indicate that many studies developing VR applications have insufficiently considered learning theories to guide instruction, and evaluations have often prioritized the usability of VR applications over concrete learning outcomes [34]. The exclusion of less stringent designs or qualitative analyses in some systematic reviews can also limit insights into valuable aspects such as user experience [31].

Moreover, there is a recognized gap in understanding the long-term effects of immersive technologies on learning outcomes. While current studies may provide insights into immediate benefits, longitudinal research tracking knowledge retention, skills development, and academic progression over extended periods is crucial but often lacking in existing reviews [16]. The considerable variability observed across studies concerning the devices used, learning domains, and specific learning dimensions also complicates the derivation of broad, generalizable conclusions [32]. Finally, aspects like cybersickness, although not universally reported, remain a potential limitation that is not always directly addressed or thoroughly investigated in the context of immersive technology use [32]. These identified limitations underscore the imperative for systematic reviews that adopt comprehensive methodologies to provide a more nuanced and complete understanding of immersive technologies' potential in higher education.

2. Method

This systematic review was conducted to synthesize the existing literature on the application of immersive technologies Virtual Reality, Augmented Reality, and Mixed Reality within higher education contexts from 2020 to 2025. The methodology adhered strictly to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines to ensure transparency, rigor, and reproducibility. The research questions guiding this review were formulated using a Population, Intervention, Comparison, Outcome framework (or Population, Exposure, Outcome for qualitative syntheses, depending on the nature of your studies). The review process comprised four distinct stages: i) identification of studies through comprehensive database searches, ii) screening of records, iii) eligibility assessment, iv) data abstraction and analysis.

2.1. Identification

A comprehensive and systematic search strategy was developed to identify all relevant scholarly literature. Initial keywords and relevant terminology were determined by examining key texts, thesauri, and existing literature on immersive technologies and higher education. The primary electronic databases searched were Scopus, Web of Science, and ERIC, chosen for their extensive coverage of high-impact research in education, technology, and social sciences.

The following detailed search strings were developed and adapted for the specific syntax and functionalities of each database:

- Scopus:

```
( "immersive technolog*" OR "virtual reality" OR VR OR "augmented reality" OR AR
  OR "mixed reality" OR MR OR "extended reality" OR XR )
AND ( "higher education" OR university OR college OR "tertiary education" )
AND ( learning OR teaching OR education OR pedagogy OR instruction OR training )
AND (PUBYEAR > 2019 AND PUBYEAR < 2026)
AND (LIMIT-TO(DOCTYPE, "ar")) AND (LIMIT-TO(LANGUAGE, "English"))
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- Web of Science:

```
TS=(("immersive technolog*" OR "virtual reality" OR VR OR "augmented reality" OR AR
    OR "mixed reality" OR MR OR "extended reality" OR XR")
   AND ("higher education" OR university OR college OR "tertiary education")
   AND (learning OR teaching OR education OR pedagogy OR instruction OR training))
Timespan: 2020–2025; Document Types: Article; Language: English
```

- ERIC:

```
("immersive technolog*" OR "virtual reality" OR VR OR "augmented reality" OR AR
 OR "mixed reality" OR MR OR "extended reality" OR XR)
AND ("higher education" OR university OR college OR "tertiary education")
AND (learning OR teaching OR education OR pedagogy OR instruction OR training)
Filters: 2020–2025; Peer-reviewed; Language: English
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The search was limited to peer-reviewed journal articles published in English between January 2020 and March 2025 (or current date if later) to capture the most recent developments in this rapidly evolving field. The initial database search yielded a total of 385 records.

2.2. Screening and Eligibility Criteria

The screening process involved assessing the identified records for their relevance to the research topic. Duplicate records were identified and removed using Mendeley reference management software, resulting in the exclusion of 72 articles. The remaining 313 unique records were then independently screened by two reviewers based on their titles and abstracts against the predefined inclusion and exclusion criteria. Discrepancies between reviewers were resolved through discussion and, if necessary, by consultation with a third reviewer.

Table 1.
Inclusion and Exclusion Criteria.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	Published between January 2020 and March 2025	Published before January 2020 or after March 2025
Literature Type	Peer-reviewed empirical journal articles	Conference proceedings, books, book chapters, review articles, editorials, theoretical papers, gray literature
Intervention	Use of VR, AR, MR, or XR for teaching and learning	Studies focusing solely on technology development without pedagogical application or evaluation
Population	Undergraduate or postgraduate university students and/or faculty	K-12 students, professional training outside academia, general public
Context	Formal higher education courses/programs	Informal learning environments, corporate training
Outcomes	Reports on outcomes such as academic performance, skill acquisition, student engagement, motivation, or perceptions.	No reported educational outcomes

After title and abstract screening, 262 articles were excluded based on these criteria, leaving 51 articles for full-text assessment. These 51 articles underwent full-text review by the two independent reviewers, applying the same eligibility criteria. A further 21 articles were excluded at this stage for reasons such as not being empirical studies, lacking clear educational outcomes, or not fitting the population/context. This resulted in a final selection of 30 studies. The study selection process is summarized in the PRISMA Flow Diagram.

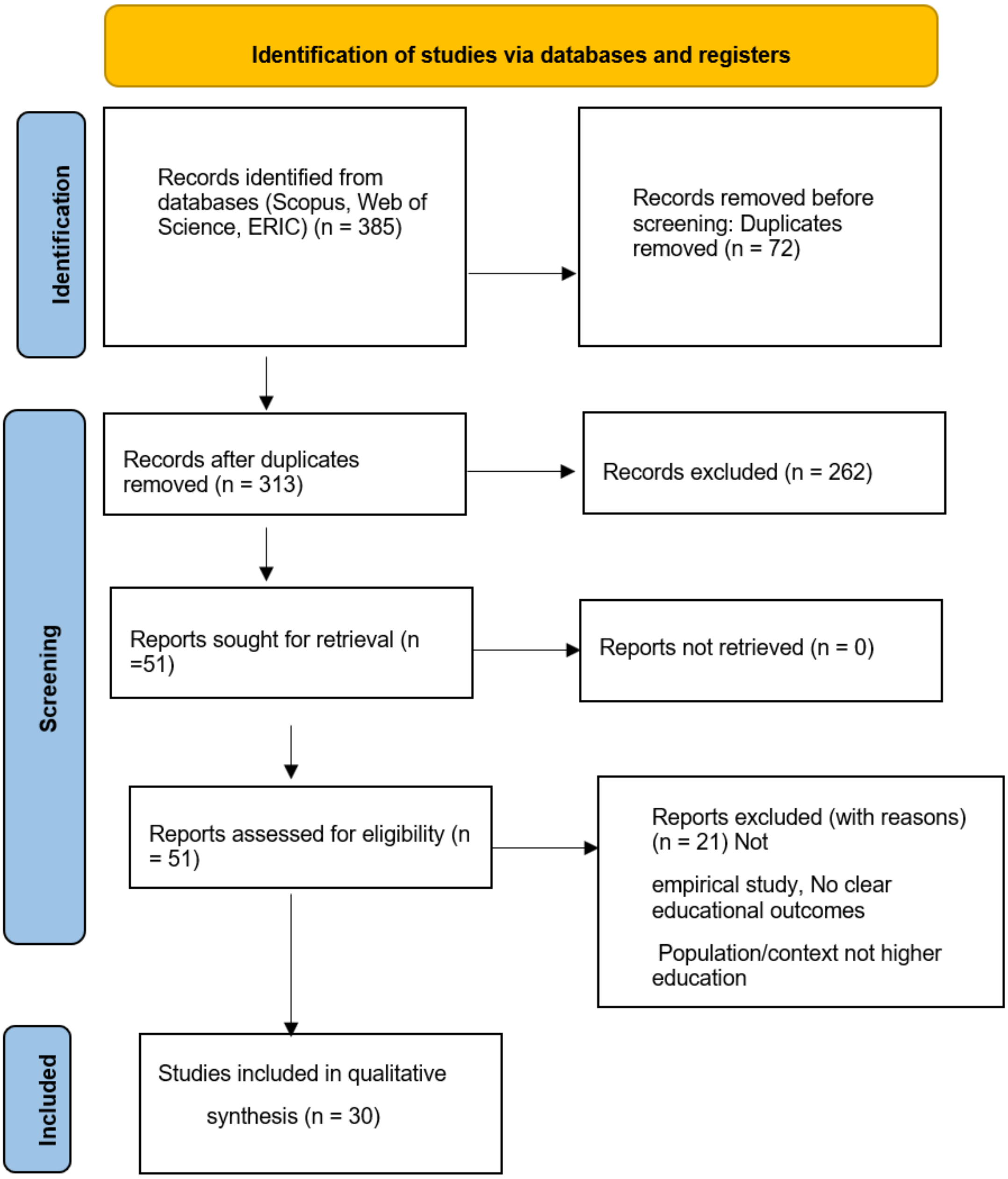

Figure 1.
PRISMA Flow Diagram of the Study Selection Process.

2.3. Data Abstraction and Analysis

Data from the 30 included studies were systematically extracted into a pre-designed, standardized data extraction form. Key information collected included: author(s) and publication year, research objectives/questions, geographical context of the study, academic discipline(s) investigated, participant characteristics (e.g., sample size, student level), specific immersive technology used (e.g., VR headset model, AR application), hardware/software details, specific pedagogical methods employed, assessment techniques utilized, and key findings related to the specified learning outcomes (conceptual understanding, skill acquisition, motivation, engagement). Data extraction was performed by one reviewer and independently verified by a second reviewer to ensure accuracy and completeness.

A thematic analysis approach, as outlined by Braun and Clarke, was employed to synthesize the findings from the included studies, aligning with the research questions. The process involved: 1) Familiarization, 2) Coding, 3) Generating Themes, 4) Reviewing Themes, and 5) Defining and Naming Themes. The validity and coherence of the final themes were refined through iterative discussion and consensus-building between the authors.

3. Findings

This systematic review, encompassing 30 peer-reviewed journal articles published between 2020 and 2025, synthesized the current landscape of immersive technologies in higher education across three primary research questions. The thematic analysis, as described in the methodology, revealed significant trends in application, pedagogical approaches, and student learning outcomes.

3.1. Academic Disciplines and Topics Utilizing Immersive Technologies

The review identified a notable diversification of immersive technology applications across various academic disciplines within higher education. While traditional strongholds such as STEM fields and medical training continue to extensively leverage Virtual Reality, Augmented Reality, and Mixed Reality for complex simulations and practical skill development [35] the analysis revealed a significant expansion. Immersive technologies are increasingly being adopted in the humanities, social sciences, and for professional skills training [36]. This signifies a growing recognition of these technologies' versatility beyond purely technical or procedural learning, demonstrating their potential to enhance learning in a wider range of subjects [37].

3.2. Instructional Approaches Employed with Immersive Technologies

The analysis of the 30 included studies highlighted an evolution in instructional strategies designed to maximize the efficacy of immersive technologies. The findings indicate a strong emphasis on pedagogical approaches that promote active and experiential learning. Collaborative learning, where students engage with peers in shared virtual environments, emerged as a prominent strategy, fostering teamwork and communication skills [38-40]. Project-based learning within virtual settings allows students to apply theoretical knowledge to solve real-world problems in simulated contexts, promoting deeper engagement and problem-solving abilities [41, 42]. Experiential learning, often through high-fidelity simulations that mirror real-world scenarios, was particularly prevalent in fields requiring practical skill acquisition, such as healthcare training and engineering [43, 44]. These approaches move beyond passive content consumption, positioning students as active participants in their learning processes [45, 46].

3.3. Impact on Student Learning Outcomes

The evidence strongly supports the benefits of immersive technologies in enhancing student learning outcomes across several key dimensions:

Conceptual Understanding: Studies consistently reported improvements in students' grasp of complex or abstract concepts, facilitated by the ability of immersive environments to provide interactive and spatial representations [24].

Practical Skill Acquisition: Particularly in disciplines requiring hands-on experience, immersive technologies proved highly effective for developing and refining practical skills in safe, repeatable, and controlled virtual environments [47].

Motivation and Engagement: A recurring theme was the significant increase in student motivation and engagement attributed to the novelty, interactivity, and immersive nature of these technologies. Students often reported higher levels of interest, enjoyment, and a greater sense of presence, which positively impacted their willingness to learn and participate [48, 49].

These positive outcomes collectively underscore the transformative potential of immersive technologies in creating impactful and effective learning experiences in higher education.

4. Discussion

This systematic review corroborates and extends existing understandings regarding the rapidly expanding role of immersive technologies in higher education. Our findings not only reinforce the widely acknowledged potential of VR, AR, and MR to enhance learning [6] but also illuminate key trends and implications for future pedagogical and technological integration within university settings.

Addressing our first research question regarding the academic disciplines and topics utilizing immersive technologies, the review reveals a significant diversification of applications beyond traditional STEM and medical fields [50, 51]. While previous reviews often highlighted the dominance of these areas, particularly in science, engineering, and medical courses [52, 53] our analysis of studies from 2020-2025 demonstrates a maturing landscape where the value proposition of immersive technologies is recognized across a broader array of subjects [51]. This includes their application in social sciences and language learning [24] humanities [54] and cultural heritage [55-57] and for fostering empathy and intercultural understanding [58]. This expansion into a broader array of subjects indicates a shift towards addressing varied learning objectives. This diversification is likely driven by several factors: increased accessibility and affordability of immersive hardware and software, growing expertise among educators across disciplines, and the recognition that immersive experiences can effectively convey abstract or culturally specific concepts. For humanities education, this signifies a profound potential to move beyond traditional text-based learning, offering immersive historical reconstructions, virtual museum tours, and interactive language learning environments that foster deeper cultural understanding and empathy, thereby making complex human experiences more tangible and relatable. This finding directly addresses a limitation of prior reviews that focused narrowly on specific disciplines, offering a more holistic view of the interdisciplinary penetration of XR technologies in recent years.

In response to our second research question concerning the instructional approaches employed with immersive technologies, the analysis highlights a crucial pedagogical shift towards active and experiential learning strategies [59, 60]. Collaborative learning in shared virtual environments, project-based learning within simulated contexts, and high-fidelity experiential simulations are predominantly utilized [61-63]. Immersive technologies are not merely tools for content delivery; they are powerful catalysts for active learning and skill development that align with 21st-century educational demands [64-66]. The effectiveness of these approaches in virtual environments speaks to the potential of immersive learning platforms to foster higher-order thinking, creativity, and practical competencies that are essential for future professionals [24]. The "critical need for pedagogical frameworks" is indeed a key takeaway. These frameworks should be rooted in established learning theories such as constructivism and experiential learning. A constructivist framework would emphasize that students actively build knowledge through interaction with the immersive environment, rather than passively receiving information. This implies designing activities where students manipulate virtual objects, solve problems in simulated scenarios, and reflect on their experiences. An experiential learning framework would involve designing learning cycles where students engage in concrete experiences within the immersive environment, reflect on those experiences, conceptualize new understandings, and actively experiment within the virtual world. This calls for deliberate instructional design that integrates pre-activity preparation, in-activity guidance, and post-activity debriefing. Such frameworks would provide educators with a structured approach to integrate immersive technologies effectively, ensuring alignment between technological affordances and learning objectives. The data from this review suggests a growing intentionality in how educators design learning experiences within immersive contexts.

Regarding our third research question on the impact of immersive technologies on student learning outcomes, the consistently positive influence on conceptual understanding, practical skill acquisition, motivation, and engagement is a robust finding of this review [16]. This reinforces previous conclusions about the benefits of immersive technologies in creating dynamic and interactive learning environments that offer interactive simulations and enhance engagement [15]. The heightened motivation and engagement reported by students are particularly important, as these factors are strongly correlated with academic success and persistence [67-71]. However, as identified in the introduction of this review, research gaps persist regarding the long-term effects of immersive technologies on learning outcomes, including knowledge retention [28]. While the current review demonstrates significant positive impacts on immediate learning outcomes and engagement, more longitudinal studies and rigorous evaluations are needed to definitively ascertain the sustained benefits, particularly concerning long-term knowledge retention and academic progression [28].

Theoretical Implications: These findings contribute to learning theories by demonstrating how immersive technologies facilitate constructivist and experiential learning paradigms, enabling students to actively construct knowledge and develop skills through direct engagement with virtual environments [72-75]. The heightened motivation observed also supports self-determination theory, suggesting that the autonomy, competence, and relatedness fostered in immersive settings contribute to intrinsic motivation and deeper learning [76-78]. The diversification of disciplines also challenges the notion that immersive learning is only suitable for procedural or highly visual subjects, suggesting broader theoretical applicability to abstract and social learning.

Practical Implications: For higher education institutions, these findings underscore the necessity of a strategic, rather than piecemeal, approach to immersive technology integration. Success hinges not solely on technological infrastructure but equally on developing comprehensive pedagogical frameworks [79, 80]. Merely introducing VR headsets without adapting instructional strategies will likely yield suboptimal results. Second, robust faculty support through training, resources, and professional development is paramount [81-83]. Addressing challenges related to effective teacher training, which have been noted as limitations in prior research [84-86] is critical to ensuring educators are equipped to design and facilitate effective immersive learning experiences.5. Conclusion

This systematic review, "Unlocking the Potential of Immersive Technologies in Higher Education," thoroughly analyzed literature from 2020 to 2025, providing a current and comprehensive understanding of the impact of Virtual Reality, Augmented Reality, and Mixed Reality within higher education. The review conclusively demonstrates that immersive technologies are potent instruments for pedagogical innovation, transcending their traditional applications in STEM and medical fields to encompass a diverse array of academic disciplines. A key finding is the significant shift towards instructional strategies that champion active, collaborative, project-based, and experiential learning within immersive environments, which are crucial for cultivating essential 21st-century skills. The evidence strongly affirms the capacity of immersive technologies to significantly enhance student learning outcomes, particularly in fostering conceptual understanding, facilitating practical skill acquisition, and notably boosting student motivation and engagement.

This work makes several contributions to knowledge by addressing critical gaps identified in previous systematic reviews. By analyzing a broad spectrum of immersive technologies across various disciplines, this review offers a more holistic and current understanding of their pervasive integration. It synthesizes evidence from the most recent period, reflecting the rapid evolution of technology and pedagogical shifts. Furthermore, it highlights the consistent efficacy of specific instructional approaches and robustly confirms the positive impact on a range of learning outcomes, thereby providing a more current and comprehensive assessment of the field.

Despite these contributions, this systematic review has certain limitations. It was restricted to English-language, peer-reviewed journal articles, which may introduce a publication bias and exclude relevant research published in other languages or formats. The chosen timeframe, while providing a current snapshot, inherently limits the inclusion of earlier foundational research. Furthermore, the variability in methodologies, reporting standards, and contextual factors across the included studies posed challenges for a direct comparative meta-analysis, necessitating a thematic synthesis approach.

Ultimately, the findings of this review articulate a clear call to action for higher education. The proven efficacy of immersive technologies in diverse educational settings mandates their strategic and thoughtful integration, rather than their adoption as mere novelties. The "so what?" is that these tools are not just enhancing learning; they are reshaping *how* we learn, offering unparalleled opportunities for engagement and skill development. To fully realize this transformative potential, it is paramount that universities invest in robust pedagogical frameworks and comprehensive faculty development programs. Equipping educators with the knowledge and skills to effectively design, implement, and assess immersive learning experiences will be the cornerstone of successful integration. Without dedicated support for faculty, the promise of immersive technologies risks being undermined by suboptimal implementation. This proactive approach will ensure that higher education institutions can leverage these powerful tools to prepare students for an increasingly complex and technologically driven future. Further research, particularly longitudinal studies, is essential to track the long-term impact on knowledge retention and career readiness, along with continued exploration of ethical considerations, accessibility, and effective mitigation strategies for challenges like cybersickness in diverse immersive learning environments.

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