INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH in PROGRESSIVE EDUCATION & DEVELOPMENT

OPEN ACCESS JOURNAL

Vol 15, Issue 3, (2026) E-ISSN: 2226-6348

Cognitive Engagement in Immersive Learning Environments: A Narrative Review and Proposed Conceptual Framework for Higher Education

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DOI Link: http://dx.doi.org/10.6007/IJARPED/v15-i3/28461

Published Online: 23 September 2026

Abstract

The use of immersive technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), extended reality (XR), and metaverse-based learning environments is transforming higher education by offering interactive, experiential, and student-centered learning opportunities. Despite the fragmented literature, however, there is little clear understanding about the impact of these technologies on learning processes and outcomes. This work aims to address this gap with a narrative review of 39 papers published in peer-reviewed, Scopus-indexed journals on the use of immersive technologies in higher education. Five main clusters emerged from the thematic synthesis: cognitive engagement and deep learning; pedagogical and instructional innovation; affective and experiential learning; immersive systems with AI; and technology adoption and usability. The results suggest that the focus of both applications shifted from technology to learning, from theory to practice, and from technology to cognition, with the latter serving as the key mechanism linking immersive environments to learning outcomes. Immersion, motivation, and interaction are benefits of using these technologies. However, the technology's impact on learning depends on the quality of instructional design and the depth of cognitive processing it elicits. The study incorporates ideas from constructivist learning theory, cognitive load theory, and self-determination theory, suggesting a cognitive-engagement-based approach to immersive learning in higher education. The review helps advance theory by clarifying the role of cognitive engagement as a mediating construct and offers practical implications for creating effective immersive learning environments.

Keywords: Immersive Technologies, Cognitive Engagement, Extended Reality (Xr), Metaverse In Education, Higher Education Learning Outcomes

Introduction

Digital technologies have revolutionized higher education, enabling innovative teaching strategies that facilitate active, experiential, and student-centered learning. Immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), and metaverse-based learning environments have gained significant attention within these innovations for their potential to provide interactive and real-world learning experiences (Shu & Gu, 2023; Predescu et al., 2023). These technologies enable the creation of learning environments through three-dimensional visualization, real-time interaction, and context simulation, thereby providing teaching spaces that cannot be obtained in the classroom. Their importance extends beyond technological innovation, as they may overcome limitations of conventional classrooms by allowing students to experience complex, practical, and otherwise inaccessible learning situations. Understanding their educational value is therefore important for improving the effectiveness of technology-enhanced higher education.

In recent years, the use of immersive technologies in higher education has gained momentum and found wide-ranging applications in various fields, such as engineering, medicine, language learning, science education, cultural studies, and business education (İbili et al., 2024; Beketov et al., 2024; Ahmed et al., 2026). Based on the current empirical evidence, immersive learning environments have been found to positively impact academic achievement, motivation, self-efficacy, collaborative learning, and offer experiential learning opportunities that are not easily accessible in a traditional classroom setting (Chen et al., 2023; Liu & Hwang, 2025; Bodur et al., 2025). As a result, universities are beginning to invest in immersive learning ecosystems that equip students with skills for the digital-age work environment. Such developments make evidence of effectiveness valuable to universities, educators, and students, as it can inform technology investment, instructional design, and the creation of more meaningful learning experiences.

These encouraging advances in technology, however, are not necessarily a panacea for successful learning. Instead, the educational benefits of immersive technologies rely heavily on the learner's capacity to process information and develop meaningful understanding in learning activities. Cognitive engagement, defined as the mental investment, strategic thinking, reflection, and deep processing of information that learners engage in during learning experiences, has come to be regarded as a key predictor of successful learning (Camilleri et al., 2025; Yin et al., 2024). Higher levels of cognitive engagement invite the learner to link new learning to existing knowledge, solve problems, and foster higher-order thinking skills that help retain knowledge over a longer period. Thus, cognitive engagement is particularly important for determining whether immersive echnologies translate their technological capabilities into actual learning benefits.

Several educational theories support the correlation between immersive technologies and cognitive engagement. Constructivist Learning Theory asserts that knowledge is constructed through interactions with real environments, and Experiential Learning Theory focuses on learning from concrete experiences and reflective observation. The Cognitive Affective Model of Immersive Learning (CAMIL) also suggests that immersion, presence, agency, and emotional reactions together support cognitive processing and meaningful learning outcomes. Likewise, the Technology Acceptance Model (TAM) has been found to account for the learners' acceptance of the immersive technology by focusing on the perceived usefulness and ease of use, while the Self-Determination Theory (SDT) emphasizes the significance of autonomy and intrinsic motivation in maintaining learners' engagement (Kemp et al., 2022;

Asadi et al., 2026). These theoretical frameworks suggest that cognitive engagement may be the key process linking immersive experiences to educational outcomes. Accordingly, examining cognitive engagement can clarify how immersive learning produces educational value and under what conditions its use is effective.

The growing body of literature shows a wide range of technological platforms, instructional approaches, and educational environments. The study has a long history, including virtual simulation (Tan et al., 2026), metaverse-enabled flipped classrooms (Dang et al., 2025), virtual museums driven by AI (Yuki & Anoegrajekti, 2026), collaborative learning using mixed reality (MR) (Tan et al., 2026), augmented reality (AR) language learning (Dang et al., 2025), and immersive laboratory simulation (Yuki & Anoegrajekti, 2026). Although several research findings indicate positive effects on engagement and learning performance, cognitive overload, technical barriers, usability problems in the learning environment, privacy concerns, and instructional design constraints have been reported as challenges that adversely affect learning effectiveness (Liang & Hu, 2026; Alshehri, 2026). This inconsistent conclusion suggests that the power of immersive technologies is greatly dependent on pedagogical implementation rather than on technological ability. While earlier review studies have examined immersive technologies from various angles, including technology adoption, virtual reality applications, and learning effectiveness, relatively few have focused on summarizing evidence on cognitive engagement as the primary mechanism by which immersive learning affects educational outcomes. Moreover, with the recent emergence of the concepts of generative artificial intelligence, intelligent tutoring systems, digital twins, and metaverse ecosystems, the field of immersive learning has experienced a significant expansion of the range of research topics, which calls for a new synthesis of empirical evidence (Asadi et al., 2026; Tan et al., 2026; Dang et al., 2025). A focused synthesis is therefore needed to establish what is known about cognitive engagement and to identify how immersive technologies can be used effectively rather than assuming that technological immersion alone improves learning.

This study is therefore a narrative review of empirical studies into cognitive engagement in immersive learning environments in higher education. The review was conducted by systematically analyzing 39 articles from Scopus-indexed journals, summarizing the current evidence and highlighting prevailing research themes, theoretical underpinnings, pedagogical approaches, and learning outcomes related to immersive technologies. This review builds on existing knowledge of cognitive engagement by incorporating insights from a range of immersive technologies and educational settings to support meaningful learning in technology-enhanced higher education. It offers directions for further research and education. The findings can support researchers in identifying future research priorities, educators in designing effective immersive learning activities, and higher education institutions in making evidence-based decisions about the adoption and implementation of immersive technologies.

Methodology

This study uses a narrative review approach to systematically synthesize empirical evidence on cognitive engagement in immersive learning environments in higher education. A narrative approach was chosen because immersive technology research has a broad spectrum of disciplines, methods, and learning situations. This method allows for thematic integration and conceptual interpretation of findings, rather than statistical aggregation. It is appropriate for detecting patterns and gaps in findings and for drawing theoretical implications across varied studies.

Data Source and Search Strategy

The literature search was conducted using the Scopus database, which is widely recognized for its comprehensive coverage of peer-reviewed literature in education, computer science, engineering, and social sciences. The search strategy was designed to capture studies related to immersive technologies and cognitive engagement in higher education contexts.

The final search query was structured as follows:

TITLE-ABS-KEY

(("virtual reality" OR "augmented reality” OR "mixed reality" OR "extended reality" OR XR OR metaverse)

AND

("cognitive engagement" OR "deep learning" OR "mental engagement")

AND

("higher education" OR universit* OR "university students" OR "tertiary education")

AND

(learning OR teaching OR pedagogy))

The literature search was conducted within defined methodological boundaries to ensure relevance, rigor, and academic quality. The search was limited to journal articles published between 2021 and 2026, reflecting the most recent developments in immersive learning technologies. Only English-language publications were considered to maintain consistency in interpretation and analysis. Furthermore, the search was restricted to four major subject areas—Social Sciences, Computer Science, Engineering, and Psychology—to capture interdisciplinary perspectives on immersive learning and cognitive engagement in higher education contexts.

Inclusion and exclusion Criteria

Only studies with empirical evidence and culturally relevant to the context were selected, so the inclusion criteria were carefully designed for this. Studies included were those that were based on VR, AR, MR, XR, or metaverse-based learning environments. Furthermore, the studies should have been conducted at the higher education or university level, as this is relevant to the tertiary learning environment. Studies had to be explicitly focused on learning processes, cognitive engagement, or pedagogical outcomes. Moreover, empirical studies using experimental, quasi-experimental, survey-based, or mixed-methods research designs were selected to ensure evidence-based results.

Studies that were review articles, meta-analyses, editorials or conceptual articles without empirical data were excluded. Research in primary and secondary schools was also excluded in order to focus on HE contexts. The studies were excluded if they did not specifically examine learning outcomes or engagement-related variables. Further, only peer-reviewed journal articles were used; conference papers, book chapters, and non-peer-reviewed articles were excluded because they lack academic rigor or methodological reliability.

Screening and Selection Process

The first search returned more publications, and these were screened using a multi-stage process. Primary: Duplicate records were eliminated. Second, the titles and abstracts were examined for relevance to immersive learning in higher education. Thirdly, articles were scanned for full text to confirm that they met the inclusion criteria. After going through this screening process, **39 empirical journal articles** were selected for analysis. This was a fine-tuned dataset that provided methodological rigor and thematic relevance and excluded non-empirical or non-relevant studies.

Data Analysis and Synthesis

A thematic narrative synthesis approach was used for analyzing the selected studies. This was done by systematically coding, categorizing, and interpreting the studies' findings. Then, all studies were reviewed for key concepts related to cognitive engagement, learning outcomes, and immersive technologies. Key concepts were first identified for each study: immersive technologies, cognitive engagement, and learning outcomes. Second, these codes were categorized into higher-order themes based on conceptual similarity and theoretical relevance. Third, cross-study comparisons were conducted to identify converging patterns, contradictions, and emerging trends. First, mechanisms employed by immersive technologies to impact cognitive engagement were identified, as were pedagogical strategies to improve the effectiveness of immersive learning. Next, learner outcomes from immersive learning environments were identified, and the theoretical frameworks used in previous research were identified.

Analytical Scope

The synthesis focused on cognitive engagement as the core construct linking immersive learning experiences and learning outcomes. Along with this, new technologies such as the integration of Artificial Intelligence, metaverse learning environments, and digital twin systems were also addressed. Variations across learning domains such as engineering, medical education, language learning, and the social sciences were also taken into account in the analysis to provide a comprehensive understanding of the field. The study will synthesize the contributions of immersive technologies to cognitive engagement and meaningful learning in higher education settings through this structured synthesis.

Findings

Thematic Structure of Immersive Learning Research

The final 39 peer-reviewed articles show a highly interdisciplinary and dynamic research field on immersive technologies in higher education, specifically VR, AR, MR, XR, and metaverse learning spaces. Based on the thematic synthesis, the technology is evident in the literature, and there is a rise in literature that emphasizes cognitive, pedagogical, and socio-emotional aspects of learning. The analyzed literature revealed five main thematic clusters: (1) immersive technology for cognitive engagement and deep learning, (2) pedagogical innovation and instructional design, (3) learner experience and affective engagement, (4) AI-integrated immersive learning systems, and (5) adoption, usability, and learning effectiveness evaluation. The narratives of these themes indicate a shift from initial research and development in immersive technologies to more learning-outcome-focused, AI-supported learning ecosystems.

Table 1
Thematic Classification of Immersive Learning Studies in Higher Education (n = 39)

Theme	Sub-theme	Technology Focus	Key Outcome	Representative Studies
Cognitive Engagement in Immersive Learning	Deep learning & attention	VR / Metaverse / XR	Increased cognitive engagement, deeper processing	Chen et al. (2023), Giussani et al. (2025), Yin et al. (2024)
Motivation & Self-Regulated Learning	Intrinsic motivation, autonomy	VR-based training	Higher motivation, reduced amotivation	Wang W. (2025), Yuki & Anoegrajekti (2026), Luria et al. (2025)
Skill Acquisition & Performance Enhancement	Academic & technical skills	VR/AR simulation	Improved learning performance, skill mastery	Bodur et al. (2025), Ahmed et al. (2026), Mojsoska et al. (2024)
Immersive Technology Adoption in Education	Acceptance factors	AR / Metaverse	Adoption driven by immersion, hedonic value	Asadi et al. (2026), Camilleri et al. (2025)
AI + Immersive Learning Integration	AI-driven personalization	AI + VR + Metaverse	Adaptive learning, improved feedback systems	Wang Y. (2025), Tan et al. (2026), Wang et al. (2025)
Emotional & Social Engagement	Emotional presence, interaction	VR / SVVR / Metaverse	Higher emotional engagement, presence	Luria et al. (2025), Yin et al. (2024), Liu & Hwang (2025)
Pedagogical Innovation & Smart Education Models	Teaching redesign	Edu-metaverse / VR platforms	Improved teaching effectiveness	Shu & Gu (2023), Nuthanapati et al. (2022), Tao & Jiang (2024)
Technical Training & Simulation Learning	Engineering & lab training	VR simulation / AR tools	Better procedural learning	Ahmed et al. (2026), Generosi et al. (2022), Kiraly et al. (2024)

Immersive Technologies and Cognitive Engagement

The literature is dominated by the idea of immersive technologies for enhancing cognitive engagement, especially in higher education settings. Research consistently indicates that VR, AR, and Metaverse environments enhance attention, immersion, and active learning, all of which are closely linked to cognitive engagement.

To illustrate, in their meta-analysis, Chen et al. (2023) found a strong overall effect of VR on student engagement (g = 0.85), especially in the cognitive dimensions of engagement. Likewise, Yin et al. (2024) note that cognitive presence and emotional engagement mediate the relationship between technology acceptance and satisfaction with learning. Not every relationship is linear, however. As shown by Liang and Hu (2026), VR increases affective engagement but may also cause cognitive overload, which can constrain direct comprehension. This indicates that the design of an immersive environment must balance stimulation with an individual's cognitive capacity. Sun (2023) also supports this argument by demonstrating that both game-based and fuzzy-learning systems yield better adaptive learning outcomes when uncertainty is appropriately handled through structured instructional design.

Pedagogical Innovation through Immersive Learning Design

The second key theme is pedagogical transformation, in which the use of immersive technologies in classroom practices like flipped learning, simulation-based learning, and experiential learning models significantly enhances academic outcomes and student motivation in medical English education, as illustrated by Ibili et al. (2024). Similarly, Yuki and Anoegrajekti (2026) show that the use of SVVR-based flipped classroom models can improve argumentative writing skills and motivate students to learn through contextual and experiential approaches. Bodor et al. (2025) concluded that although the cognitive results are similar to those of other simulation techniques, VR CPR training is more effective for psychomotor skills and engagement.

Taken together, the results suggest that immersive technologies are most effective when integrated into a structured pedagogical approach rather than as standalone technologies. The observation is well supported by the constructivist learning theory, which emphasizes that knowledge is built through active participation and experience in context. Hence, immersive technologies are not just digital substitutes but also pedagogical enablers that can facilitate experiential, inquiry-based, and learner-centered pedagogies.

Affective, Emotional, and Experiential Learning Dimensions

The third theme emphasizes the emotional and experiential aspects of immersive learning, which are increasingly acknowledged as key factors in learning effectiveness.

As shown by Luria et al. (2025), VR can significantly increase emotional engagement, in the form of interest, empathy, and inspiration, especially in sensitive educational topics like Holocaust education. Likewise, Alshehri (2026) demonstrates that the use of AR in language learning increases motivation, persistence, and self-directed learning by providing context-mediated interaction and gamified interaction. Moreover, Wang (2025) notes that VR sports training enhances learners' intrinsic motivation and self-regulation, suggesting that VR environments extend beyond cognitive learning to influence learners' behavioral and emotional learning processes. However, some research warns that it can be cognitively demanding or hinder learning if not structured properly. Thus, there should be a strategic balance among emotional engagement, cognitive load, and instructional clarity. The theme is closely related to Self-Determination Theory, focusing on the importance of autonomy, competence, and relatedness in preserving intrinsic motivation in immersive settings.

AI-Integrated Immersive Learning Systems and Digital Ecosystems

A rapidly emerging theme is the integration of artificial intelligence with immersive learning environments, marking a shift toward intelligent, adaptive, and personalized educational systems. Tan et al. (2026) argue that the learning outcomes of the virtual museum system could be greatly enhanced by incorporating knowledge graphs and generative AI tools, thereby making the system much more useful. Asadi et al. (2026) expand the TAM to include cognitive engagement, immersion, and hedonic motivation, and find that AI-powered metaverse environments have a strong impact on behavioral intention. Dewangan and Chandrakar (2024) propose blockchain-integrated digital twin systems for educational data management to ensure secure, adaptive access to educational data, while Wang (2025) presents AI-based recommendation systems that personalize the learning experience in digital media art education.

Overall, these research efforts indicate that the future of immersive learning is a hybrid AI–XR system featuring personalized learning, adaptive feedback, and intelligent tutoring systems. This is part of a trend toward Industry 5.0 education paradigms that involve human-centric AI systems to enhance experiential and cognitive learning.

Technology Adoption, Usability, and Learning Effectiveness

The last theme is dedicated to educational applications of immersive technologies and their adoption and use in educational contexts. Cognitive presence and hedonic motivation have been shown to affect the adoption of AR in engineering education significantly (Camilleri et al., 2025), and perceived usefulness and educational compatibility have been identified as significant factors in the acceptance of VR in education (Kemp et al., 2022). VR has also been shown to improve usability and reduce cognitive load compared to traditional instructional approaches, as reported by Giussani et al. (2025), while learning is comparable across modalities. The results indicate that immersive technologies are generally user-friendly for students but only effective when they are perceived to have good system design, alignment with instruction, and ease of use. Therefore, adoption is not a simple technical process but is strongly shaped by pedagogical design and learners' psychology.

Theoretical Foundation and Conceptual Framing

Immersive technologies such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and metaverse environments have revolutionized higher education pedagogy by changing how learning is delivered. Although there has been growing empirical interest in these technologies, the theoretical understanding of their learning outcomes remains fragmented. Thus, this study proposes that cognitive engagement is the key mediating mechanism linking immersive learning environments to educational outcomes and provides three complementary theoretical perspectives: Constructivist Learning Theory, Cognitive Load Theory, and Self-Determination Theory.

Constructivist Learning Theory and Immersive Learning

Constructivist learning theory holds that knowledge is not transmitted from the teacher to the learner but is constructed by the learner as they interact with the environment. The immersive technologies fit this view very well, as they enable experiential, contextual, and situated learning. VR learning has been shown to support deep learning by enabling students to manipulate and visualize content and engage with it actively, as seen in studies such as İbili et al. (2024) and Yuki & Anoegrajekti (2026). Likewise, Liu & Hwang (2025) indicate that the overall improvement in critical thinking and self-efficacy through SVVR-based project learning is achieved through experiential engagement. Constructivist views of immersion contend that the immersion experience serves as scaffolding, connecting abstract concepts to practical applications and thereby enhancing knowledge construction processes.

Cognitive Load Theory and Learning Constraints in Immersive Environments

Immersive technologies increase engagement but also increase cognitive complexity. According to the Cognitive Load Theory, the human working memory imposes limits on learning efficiency, especially in highly stimulating situations. Liang & Hu (2026) demonstrate that VR-based learning can increase affective engagement but not always comprehension, as cognitive overload can occur. Likewise, Giussani et al. (2025) conclude that VR can reduce learners' sense of workload compared to slides, but poorly designed VR tasks can overwhelm learners. This indicates that the best way to increase cognitive engagement is not just to immerse the learner, but to optimize immersion to avoid introducing unnecessary cognitive load. This requires a balance between sensory stimulation and cognitive clarity to design effective learning that maximizes germane cognitive processing.

Self-Determination Theory and Affective Engagement Linkage

Self-Determination Theory (SDT) is a significant motivational theory in understanding student engagement in immersive learning. SDT focuses on the three components of autonomy, competence, and relatedness as fundamental sources of intrinsic motivation. This relationship is supported by empirical evidence. VR-based sports training has been found to improve intrinsic motivation and self-regulation in training (Wang, 2025), and AR-supported language learning has been shown to increase persistence and autonomy through contextual interaction and feedback mechanisms (Alshehri, 2026). Also, Luria et al. (2025) emphasize that VR can evoke emotional engagement, such as interest and inspiration, which are important affective factors that contribute to persistent cognitive engagement. So SDT makes sense in explaining why an immersive environment is not only able to enhance attention but also to maintain learner motivation in emotionally relevant and self-directed learning experiences.

Cognitive Engagement as the Central Mediating Mechanism

This study incorporates the most recent theories of constructivism, cognitive load, and motivation to position cognitive engagement as the mediating variable that explains the relationship between the use of immersive technologies and learning outcomes. Cognitive engagement refers to the extent to which learners use their thinking, effort, and strategy in learning activities. In all the literature reviewed, cognitive engagement is a recurrent factor identified as a determinant of learning success. Cognitive engagement, for instance, has been identified by Chen et al. (2023) as the most important moderator of VR effectiveness in higher education. Yin et al. (2024) also find that technology acceptance significantly mediates the relationship between learning satisfaction and cognitive presence. However, as Liang & Hu (2026) point out, it is important to distinguish between emotional stimulation and deeper cognitive learning, as emotional content does not always correspond to deeper cognitive engagement. Thus, cognitive engagement is defined as the connection between the immersive experience and learning performance, rather than as a direct result of exposure to the technology.

Proposed Conceptual Framework

Based on the theoretical synthesis and literature evidence, the following conceptual relationships are proposed:

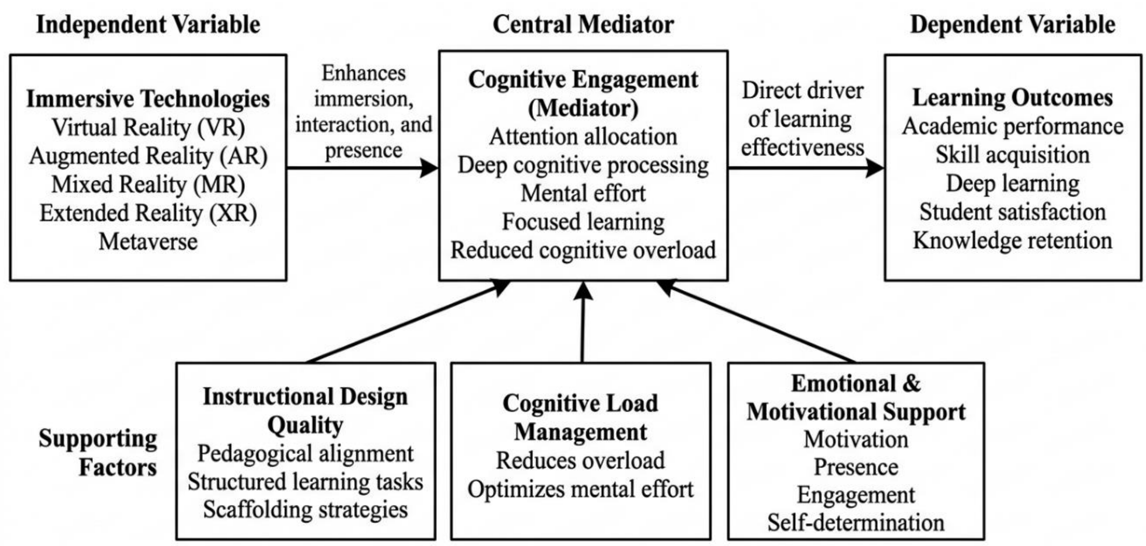

Figure 1. Proposed Conceptual Framework for Immersive Technologies and Cognitive Engagement in Higher Education (Source: Authors' own work)

This study develops a conceptual framework that explains how immersive technologies—namely Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), and metaverse-based environments—affect learning outcomes in higher education, with cognitive engagement as a central mediating mechanism.

Immersive Technologies

The concept of immersive technologies refers to interactive, simulation-based digital environments that create immersive learning, presence, and interactivity. Previous research has shown that VR/AR/MR environments enhance student engagement, attention, and participation by providing learners with realistic and interactive learning spaces (Chen et al., 2023; Giussani et al., 2025; Predescu et al., 2023). VR training in STEM and health education, for instance, has been shown to boost engagement and perceived learning effectiveness significantly (Bodur et al., 2025; Mojsoska et al., 2024), and AR learning systems have been demonstrated to enhance interaction and behavioral intention in educational settings (Kamarudin et al., 2023; Alshehri, 2026).

Cognitive Engagement

Cognitive engagement is introduced as the main mediating variable in this model, representing the mental investment, deep processing, and attention learners devote to learning tasks. Empirical studies have found that immersive environments strongly impact cognitive engagement, creating a sense of presence and reducing passive learning patterns (Chen et al., 2023; Yin et al., 2024; Luria et al., 2025). Research on VR-based learning has consistently demonstrated that it leads to greater cognitive engagement than conventional learning, especially in higher education settings (Giussani et al., 2025; Wang et al., 2025). In addition, instructional design quality, emotional stimulation, and optimization of cognitive load in immersive environments affect the level of cognitive engagement (Hou & Lan, 2026; Shu & Gu, 2023).

Learning Outcomes

In this study, learning outcomes are defined as a multi-dimensional construct which includes academic achievement, skill acquisition, deep learning, and learner satisfaction. Findings from immersive learning studies indicate that VR/AR interventions consistently enhance academic outcomes, problem-solving skills, and skill acquisition (Ahmed et al., 2026; Zhai, 2023; Liang & Hu, 2026). VR applications in Engineering and medical education, for example, have been found to enhance procedural and declarative knowledge outcomes (Mojsoska et al., 2024; Beketov et al., 2024). Likewise, learning satisfaction and performance enhancement, based on learning engagement, have been correlated with the use of the metaverse and AI in learning environments (Yuki et al., 2026; Wang & Bao, 2026).

Theoretical Integration

This framework is based on Constructivist Learning Theory, Cognitive Load Theory, and Self-Determination Theory. Constructivism is the theory that explains how immersive environments aid in the construction of knowledge through experiential learning. The Cognitive Load Theory explains how design features of an immersive system manage cognitive load and how this can affect learning effectiveness. The mechanisms of autonomy, engagement, and intrinsic motivation, which are strengthened by immersive and interactive learning environments, are explained within the field of Motivation using S.D.T. (Shu & Gu, 2023; Yin et al., 2024; Chen et al., 2023).

Discussion

The results of this narrative synthesis illustrate that immersive technologies applied in higher education do not have the same impact on learning outcomes. Rather, their impact is mediated by a series of cognitive and motivational processes, and cognitive engagement is the key pathway for explaining it. This is consistent with the recent calls in the literature for learning process-based approaches to learning (Chen et al., 2023; Yin et al., 2024). The evidence indicates that the impact of VR, AR, MR, and metaverse environments on academic performance is indirect, operating through their effects on learners' meaning-making processes, attentional control, and cognitive investment. This means that immersive technologies are seen as facilitators of cognitive conditions, not as goals to be achieved.

In all the reviewed studies, cognitive engagement is the most critical mediator between immersive exposure and learning outcomes. This corroborates the thesis that immersion does not produce learning improvements unless learners actively process, organize, and apply the information. According to Chen et al. (2023), VR engagement is significantly higher than that of traditional classroom learning, particularly cognitive engagement, with a large effect size. However, Liang and Hu (2026) demonstrate that this association can be complicated by immersive environments that increase affective engagement without necessarily increasing comprehension under cognitive overload. This tension is of theoretical significance. It presents evidence that immersion is not a sufficient condition for cognitive engagement, but rather a function of the relationship between stimulation and cognitive capacity. In the context of Cognitive Load Theory, the amount of sensory input may affect learning efficiency due to an excess of germane processing (Giussani et al., 2025). Therefore, cognitive engagement must be seen as a fragile, design-dependent concept rather than a consequence of using immersive technology. One theoretical question that has been addressed in the literature repeatedly is whether the term "immersion" is synonymous with learning effectiveness. Presence, motivation, or enjoyment of learning is often found to be high (Luria et al., 2025; Wang, 2025) but not necessarily in proportion to learning gains. This implies that to be immersed, the learner needs to be cognitively active, or meaningfully involved, too. For instance, Liang and Hu (2026) make a clear distinction between affective enhancement and comprehension, demonstrating that the former does not automatically lead to the latter, except when there is a cognitive match between the VR task and the perceived task demands. Similarly, VR training programs in STEM and healthcare (Bodur et al., 2025; Giussani et al., 2025) have shown that, although they enhance usability and engagement, they do not significantly differ in learning outcomes. This pattern represents an important theoretical paradigm shift: Presence is a precursor to engagement; it is not engagement itself. In other words, immersive environments need to be created to transform experiential richness into structured cognitive processing.

One major finding from the synthesis is that instructional design plays an important role in moderating the relationship between immersive technology and cognitive engagement. The findings from studies on structured pedagogies such as flipped classroom, simulation-based training, and the SVVR project-based learning are consistently positive for learning outcomes (İbili et al., 2024; Yuki & Anoegrajekti, 2026). The results of this study suggest that the most effective use of immersive technologies is through explicit pedagogical scaffolding. Constructivist viewpoints would align with the assertion that they need structured coaching to turn their experience into knowledge. If not provided, virtual environments can become an educationally unproductive cognitive disorder. Thus, the nature of instructional design is a boundary condition for cognitive engagement, dictating whether learning will be deep or shallow.

Emotional and affective engagement are also important factors in an immersive learning environment, though they are secondary to cognitive engagement. Research has consistently demonstrated that VR and AR environments positively impact motivation, interest, and emotional engagement (Luria et al., 2025; Alshehri, 2026; Wang, 2025). However, there is no guarantee that emotional engagement automatically translates to effective learning. Where it is not tied to learning goals, it can even be a distraction to cognitive processing in some instances. This is seen in results in which pupils report high enjoyment and moderately high or unchanged cognitive performance (Liang & Hu, 2026; Giussani et al., 2025). This further reinforces a key theoretical development: emotional engagement should not be considered an immediate indicator of learning success, but rather a means to sustained cognitive engagement. From an SDT perspective, emotion facilitates autonomy and interest but still requires cognitive investment for knowledge acquisition. One of the key findings from the literature is the integration of AI technologies into immersive environments. The use of AI-powered tools, including virtual museums, adaptive recommendation systems, and digital twins, has been on the rise to enhance learning experiences and personalization (Tan et al., 2026; Wang, 2025; Dewangan & Chandrakar, 2024). Such systems are a departure from traditional "immersive" systems toward what may be described as "cognitive ecosystems," in which learner behavior dynamically influences how content is delivered. Theoretically, this evolutionary shift enhances the role of cognitive engagement by facilitating real-time adaptation to learners' needs, reducing unnecessary cognitive load, and maximizing engagement opportunities. However, according to Asadi et al. (2026), privacy concerns and perceived risk can have a negative moderating effect on adoption, suggesting that technological sophistication is not enough to ensure educational effectiveness. The use of AI adds depth and enhancement to the cognitive engagement model.

Limitations and Future Research Directions

One might raise several questions about the limits of this study, which, of course, present new avenues of research. First, the analysis is based on a narrative synthesis of 39 peer-reviewed journal articles published in Scopus, a peer-reviewed, searchable, digital repository of scientific and academic literature that is indexed and abstracted. First, the analysis is based on a narrative synthesis of 39 peer-reviewed journal articles published in a searchable, digital repository of scientific and academic literature, Scopus, which is indexed and abstracted. This guarantees that a high-quality, relevant evidence base is available, but may exclude emerging conference proceedings, early-stage empirical studies, and industry-leading innovations that are often the first source of knowledge in rapidly changing areas of immersive technology. This means that the review does not necessarily reflect the latest advances in AI-powered immersive systems and generative AI–augmented learning environments.

Second, the study focuses on a strong theoretical approach with the lens of cognitive engagement, which could also be regarded as a conceptual limitation. Immersive learning processes were inevitably simplified in the study because the author saw the mediating process of embedding cognitive context as the center of all processes. Recent research has also indicated that learning in immersive environments is influenced by concurrent psychological and behavioral factors, including flow experience, self-regulation, social presence, and emotional regulation (e.g., Luria et al., 2025; Yin et al., 2024). Multi-mediator or layered models should thus be considered in future research, incorporating cognitive, emotional, and social aspects to gain a more comprehensive understanding of learning outcomes.

Third, there is an uneven distribution of reviewed studies across disciplines, with a high number in STEM, medical education, engineering, and language learning. The disciplinary imbalance prevents the drawing of conclusions for broader areas of higher education, including the social sciences, humanities, and teacher education. Furthermore, the studies included are mostly based on short-term experiments or quasi-experimental designs, which limit the ability to understand how cognitive development in immersive environments unfolds over longer periods. Future research should therefore follow several directions. From a theoretical perspective, further development of the concept of cognitive engagement in immersive settings is required, as it needs to be broken down into deeper cognitive processes, such as metacognition, SRL, and knowledge transfer mechanisms. Furthermore, incorporating additional theories will enhance the study’s explanatory depth; future studies could draw on flow theory, sociocultural learning theory, and embodied cognition.

Methodologically, it is suggested to use approaches grounded in longitudinal and learning analytics to analyze the effects of cognitive engagement over time in immersive environments, rather than only in the short term. Lastly, as the AI-powered immersive ecosystem rapidly evolves, future studies should examine the dynamic effects of adaptive AI systems, digital twins, and metaverse platforms on cognitive engagement and on their potential to optimize or disrupt deep learning.

Conclusion

This study uses a narrative synthesis to present a structured synthesis of 39 peer-reviewed articles on immersive technologies in higher education, specifically VR, AR, MR, XR, and learning environments with the metaverse. The results show that the field is moving away from technology-related experimentation and toward theoretically informed studies of the learning process, specifically including cognitive engagement.

In the literature examined, cognitive engagement is the primary factor driving the impact of immersive technologies on learning outcomes. The immersive environment increases attention, motivation, and emotional involvement, but learning effectiveness depends on the quality of the learning process and the depth of cognitive processing.

The study advances theory by combining the ideas from the three aforementioned theories (constructivist learning theory, cognitive load theory and self-determination theory) into a coherent cognitive engagement framework. It also furthers understanding of how immersive technologies work not as a direct driver of learning but as an enabler of cognitively rich learning environments.

First, in practice, the results indicate that design strategies aimed at fostering cognitive engagement should be implemented when using immersive technologies in higher education. Increasing immersion alone is not enough unless it is tied to carefully designed pedagogical scaffolding and cognitive processing demands.

Acknowledgements

This study forms part of the research outputs of PJP PERSPEKTIF 2024 (Grant No. PJP/2024/IPTK/PERINTIS/SA0050). The authors would like to acknowledge the support provided throughout the development of this project.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of interests

The authors declare no conflict of interest.

AI Declaration

The authors used generative AI tools, specifically ChatGPT and Grammarly, for language editing and formatting purposes only. The authors retain full responsibility for the accuracy, originality, and integrity of the manuscript.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author (s).

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