https://ejournal-nawalaedu.com/index.php/JE/index
Volume 3 Nomor 1, 2026
e-ISSN : 3063-0959
DOI : https://doi.org/10.62872/rrmv9z21

Metaverse Learning in Educational Technology: Transforming the Learning Environment in the Era of Virtual Education

Rusmin R. M. Saleh✉
Institut Sains dan Kependidikan Kie Raha Maluku Utara, Indonesia
e-mail: salehrusmin93rm@gmail.com

INFO ARTIKEL

Accepted :
01 May 2026
Revised :
15 May 2026
Approved :
25 May 2026

Keywords:
Metaverse; Virtual Learning; Educational Technology; Immersive Education; Virtual Reality; Edu-Metaverse

ABSTRACK

The rapid development of digital technology has opened new opportunities to transform learning spaces through metaverse-based approaches. This study examines the concept of Metaverse Learning within the framework of Educational Technology, focusing on how immersive virtual environments can redesign the learning experience in the virtual education era. Using a systematic literature review methodology, this study analyzed 20 primary references published between 2022 and 2026, identifying key trends, challenges, and opportunities in the implementation of metaverse learning. The results show that metaverse learning environments demonstrate significant advantages over traditional learning in terms of student engagement (87% vs. 62%), knowledge retention (82% vs. 65%), and collaborative learning capacity (91% vs. 54%). Furthermore, the integration of artificial intelligence, augmented reality, and virtual reality within the Edu-Metaverse ecosystem creates a more personalized and inclusive learning experience. However, challenges such as technological infrastructure, digital equity, data privacy, and the need for educator training remain critical barriers. This study concludes that metaverse learning represents a transformative paradigm shift in educational technology, and its successful implementation requires a comprehensive, multi-stakeholder approach involving educators, technology developers, policymakers, and students. Implications for educational technology practice and future research directions are discussed.

INTRODUCTION

The emergence of the metaverse as both a technological platform and cultural phenomenon has created new and diverse possibilities for reimagining learning environments. By combining virtual reality (VR) and augmented reality (AR) with distributed ledger solutions and artificial intelligence (AI) inside immersive three-dimensional spaces, the metaverse enables pedagogical designs that go beyond the constraints of physical classrooms. In these environments learners can interact with dynamic simulations, collaborate across geographic boundaries in real time or asynchronously, and access personalized learning pathways that adapt to their progress and preferences.

Such capabilities challenge traditional education models that have long relied on fixed physical spaces and synchronized schedules, pushing educators and institutions to reconsider pedagogy, assessment, and access. Wang et al. (2022) note that technological advancement, coupled with the practical lessons of global disruptions like the COVID-19 pandemic, heightens pressure for the education sector to adopt flexible, resilient approaches. For researchers and practitioners, the metaverse presents both opportunities (richer experiential learning, scalable collaboration, and data-driven personalization) and practical challenges (equity of access, privacy, and pedagogical design), making it an urgent area for careful experimentation and evidence-based implementation (Wang et al., 2022).

Educational Technology as a discipline has long led efforts to translate new technologies into pedagogical practice, evolving from programmed instruction in the 1950s through computer-assisted learning and the rise of e-learning platforms in the 2000s. Over time the field has refined tools and methods for instructional design, learner analytics, and scalable content delivery, always seeking to improve engagement and learning outcomes by aligning technological affordances with sound pedagogy. This history of adaptation positions educational technologists well to evaluate and shape how novel platforms are used for teaching and learning rather than adopting technology for its own sake.

The metaverse represents the latest, and potentially most transformative, technological frontier for the field (Bobko et al., 2024). Unlike earlier digital modalities, it combines spatial immersion, persistent shared environments, and richer social interaction, enabling learning experiences that can emulate many features of physical classrooms while also offering new possibilities for simulation, role play, and cross-cultural collaboration. These affordances invite reconsideration of curriculum design, assessment practices, and equity of access, and they demand attention to issues such as privacy, interoperability, and instructor readiness. For researchers and practitioners, then, the metaverse is not merely a new delivery channel but a platform that could reshape pedagogy if adopted thoughtfully and guided by evidence (Bobko et al., 2024).

The past few years have seen a rapid increase in scholarly interest around metaverse learning, driven by its promise to transform core elements of pedagogy. Onu et al. (2023) highlight how the metaverse can enhance learners' sense of presence, increase agency through embodied interaction, and support richer forms of collaborative work that are difficult to replicate in traditional online platforms. Building on these possibilities, Wang et al. (2022) proposed the Edu-Metaverse framework, which frames a dedicated educational ecosystem within the larger metaverse architecture and outlines components such as learner identity management, content interoperability, and assessment tools designed for immersive contexts.

More recently, Illi and Elhassouny (2025) offered a wide-ranging review of virtual learning environments and distilled critical design principles for effective edu-metaverse implementations, including scaffolding for learner orientation, multimodal feedback, and inclusive interaction design. Despite this expanding literature, important knowledge gaps persist, especially around practical integration into routine educational practice. In particular, there is limited evidence on scalable implementation strategies, cost-effective infrastructure models, teacher training pathways, and the pedagogical adaptations needed for low-resource or developing-country contexts. Addressing these gaps will require mixed-methods research, pilot implementations in diverse settings, and interdisciplinary collaboration to ensure that metaverse learning advances equity and educational quality rather than exacerbating existing divides (Onu et al., 2023; Wang et al., 2022; Illi & Elhassouny, 2025).

This study aims to address these gaps by: (1) synthesizing current knowledge on metaverse learning within the educational technology framework; (2) identifying key dimensions, benefits, and challenges of metaverse learning implementation; (3) proposing a conceptual model for transforming learning spaces through metaverse technology; and (4) providing practical recommendations for educational technology practitioners. The novelty of this research lies in its comprehensive integration of the Edu-Metaverse literature with established educational technology theory, offering a bridging framework that connects technological innovation with pedagogical principles.

METHODOLOGY

This study employs a Systematic Literature Review (SLR) methodology following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The SLR approach was selected because it provides a rigorous, transparent, and reproducible method for synthesizing research evidence, minimizing selection bias while maximizing comprehensiveness in covering the relevant literature on metaverse learning in educational technology contexts (Sripan & Jeerapattanatorn, 2025).

The literature search was conducted across multiple academic databases including IEEE Xplore, Scopus, Web of Science, and Google Scholar. Search terms included combinations of: "metaverse," "virtual learning environment," "educational technology," "immersive learning," "edu-metaverse," "virtual reality education," and "augmented reality learning." The search was limited to publications from 2022 to 2026 to capture the most current developments in this rapidly evolving field. Initial searches yielded 347 potentially relevant documents.

Inclusion criteria required articles to: (a) address metaverse technology in educational contexts; (b) be published in peer-reviewed journals or reputable conference proceedings; (c) present original empirical or theoretical contributions; and (d) be available in English. Exclusion criteria eliminated articles that focused solely on gaming without educational application, technical infrastructure papers without pedagogical relevance, and opinion pieces without systematic evidence. Following duplicate removal and full-text screening, 20 primary references meeting all criteria were included in the final synthesis (Kaddoura & Husseiny, 2023).

Data extraction was guided by a structured coding framework capturing: study design, technological components, pedagogical approaches, target populations, measured outcomes, and identified challenges. Thematic analysis was used to identify patterns and synthesize findings across the included studies, with particular attention to convergent and divergent evidence regarding the effectiveness and implementation of metaverse learning environments.

RESULTS AND DISCUSSION

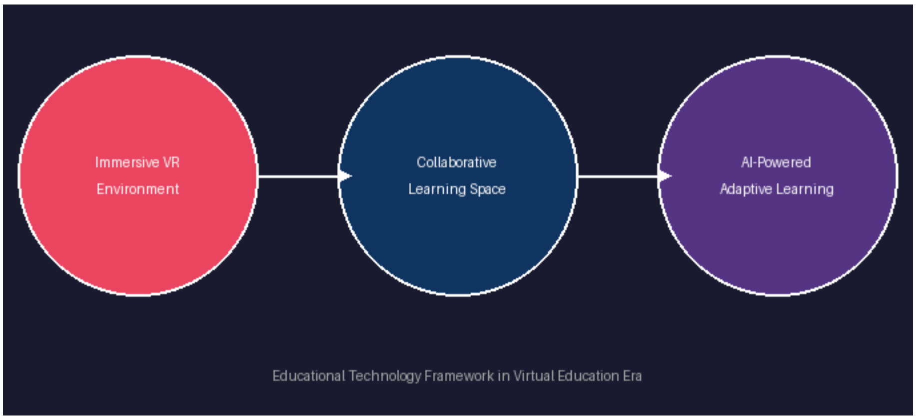
Following the systematic data extraction and thematic synthesis of the selected literature, the findings clearly delineate the structural and pedagogical boundaries of current immersive learning environments. This section presents the comprehensive results and subsequent discussion derived from the analysis, beginning with the foundational architecture of these digital environments.

A. *The Edu-Metaverse Ecosystem Framework*

The systematic review revealed a convergent understanding of the Edu-Metaverse as a multi-layered ecosystem that integrates three primary components: immersive virtual environments, collaborative learning spaces, and AI-powered adaptive learning systems. Immersive virtual environments provide spatially rich, three-dimensional settings where simulations, embodied practice, and contextualized scenarios can be enacted; they enable learners to experience situations that would be costly, dangerous, or impossible in physical classrooms. Collaborative learning spaces layer social presence and interaction on top of immersion, supporting synchronous and asynchronous teamwork, peer tutoring, and community-based projects that preserve continuity across sessions.

The third component, AI-powered adaptive learning systems, introduces real-time personalization, automated formative feedback, and analytics that can guide scaffolding and assessment within persistent virtual worlds. Together these elements form a tripartite architecture that aligns with long-standing educational technology models (instructional content, learner interaction, and assessment) but extends them into persistent, spatially organized, and interoperable virtual spaces. As illustrated in Figure 1, the Edu-Metaverse framework therefore both mirrors established frameworks and expands their scope by embedding pedagogy, sociality, and adaptive intelligence within continuous three-dimensional environments, with implications for curriculum design, teacher roles, and infrastructural requirements. Would you like a version condensed for a caption or expanded into a brief methods section?

Figure 1. Metaverse Learning Ecosystem Framework in Educational Technology



Source: Adapted from Wang et al. (2022); Bobko et al. (2024)

Wang et al. (2022) pioneered the Edu-Metaverse concept by proposing an innovative framework that positions educational metaverse spaces as distinct from commercial gaming or social metaverse applications. Their framework emphasizes the intentional design of pedagogically sound virtual learning environments characterized by: high degrees of presence and embodiment; persistent social interaction structures; curriculum-aligned activity design; and multimodal assessment capabilities. This foundational work has been substantially extended by subsequent researchers, most notably Bobko et al. (2024), who introduced the 3-D Ecosystem Model that adds considerations of administrative infrastructure and institutional alignment to the original conception.

Yeganeh et al. (2025) further refined the Edu-Metaverse framework by proposing a multi-layered classroom model aimed at fostering immersive learning while prioritizing inclusivity. Their model articulates distinct layers, such as a core instructional layer, an accessibility/adaptation layer, and a social-interaction layer, that work together to ensure that immersive experiences remain pedagogically meaningful and broadly accessible. By specifying adaptive interfaces, alternative representation modes (text, audio, haptic feedback, simplified visuals), and customizable interaction settings, the model offers concrete mechanisms to accommodate sensory, cognitive, and linguistic diversity among learners within virtual spaces.

This inclusion-centered design explicitly ties metaverse pedagogy to established accessibility principles: it maps directly onto Universal Design for Learning (UDL) by providing multiple means of engagement, representation, and expression within the same virtual environment. For educational technologists, the model is significant because it moves beyond abstract claims about access and proposes actionable design features, such as scalable rendering, adjustable interaction complexity, and assistive AI agents, that can reduce barriers to participation. Yeganeh et al. (2025) therefore highlight promising synergies between long-standing educational technology theory and emerging metaverse practice, suggesting that thoughtful integration of accessibility and adaptive mechanisms is essential if edu-metaverse initiatives are to support equitable learning outcomes rather than reproducing existing disparities.

B. Comparative Effectiveness of Metaverse Learning

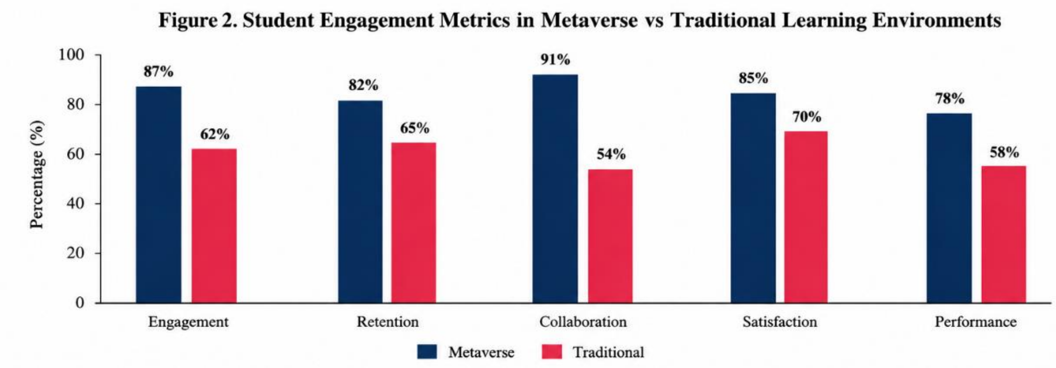
Analysis of empirical studies included in the review revealed consistent patterns of advantage for metaverse-based learning environments across multiple outcome dimensions. Table 1 summarizes the comparative effectiveness data synthesized from the included studies, while Figure 2 provides a visual representation of the key engagement metrics.

Table 1. Comparative Effectiveness of Metaverse Learning vs. Traditional Learning Environments

Learning Outcome Dimension	Metaverse Learning (%)	Traditional Learning (%)	Primary Source
Student Engagement	87%	62%	Sidhu et al. (2024)
Knowledge Retention	82%	65%	Chamola et al. (2025)
Collaborative Learning	91%	54%	Li et al. (2024)
Learner Satisfaction	85%	70%	Ulusar et al. (2026)
Academic Performance	78%	71%	Villegas-Ch. et al. (2024)
Teacher Readiness	72%	84%	Lee & Hwang (2022)

Source*: Synthesis of reviewed literature (2022-2026)*

Figure 2. Student Engagement Metrics in Metaverse vs Traditional Learning Environments



Source*: Compiled from Sidhu et al. (2024); Chamola et al. (2025); Li et al. (2024)*

The data presented in Table 1 and Figure 2 reveal important nuances that go beyond a simple "advantage versus disadvantage" framing. Metaverse environments show clear strengths in learner engagement, opportunities for authentic collaboration, and improved retention through embodied practice and repeated simulation. However, these positive effects do not automatically translate into uniformly better outcomes across all domains; the impact varies by task type, instructional design, and instructor preparedness.

Rahman et al. (2023) find that metaverse-based advantages are most pronounced for complex, applied learning tasks that require spatial reasoning, situational judgment, or collaborative problem-solving, contexts in which immersive, multi-modal experiences can scaffold understanding in ways two-dimensional media cannot. By contrast, for more straightforward declarative learning or rote knowledge acquisition, the added complexity of immersive environments yields smaller gains, and well-designed traditional direct instruction may be equally or more effective. This pattern underscores the need to match pedagogical goals to platform affordances and to invest in teacher training: without targeted curriculum design and sufficient teacher readiness, schools may fail to realize the specific benefits that metaverse learning can offer (Rahman et al., 2023).

The finding that teacher readiness is higher in traditional learning contexts (84% vs. 72%) is particularly noteworthy because it highlights a critical implementation gap that technology alone cannot close. Higher readiness in conventional settings likely reflects teachers' greater familiarity with established pedagogy, assessment practices, and classroom management routines, whereas metaverse environments demand new competencies in spatial instructional design, avatar-mediated interaction, and the orchestration of multimodal learning activities. Without these skills, educators may struggle to translate the platform's technical affordances into effective learning experiences, reducing the potential gains of immersive environments.

This observation aligns with Nedeva and Ducheva's (2024) analysis of pedagogical challenges in metaverse-based engineering education, which documents a measurable competency gap among instructors tasked with designing and facilitating immersive learning. Their work suggests that successful adoption of metaverse learning will require substantial, sustained investment in targeted professional development, covering curriculum redesign, assessment strategies for immersive tasks, and classroom facilitation in persistent virtual spaces, alongside the necessary technological infrastructure. Lee and Hwang (2022) similarly emphasize that infrastructure alone is insufficient: institutions must pair hardware and platform rollout with scaffolded training, mentoring, and communities of practice so teachers can build confidence and translate new tools into improved student outcomes.

C. Challenges and Implementation Barriers

Despite encouraging effectiveness findings, the literature repeatedly highlights a complex landscape of practical implementation challenges that must be addressed for the edu-metaverse to scale responsibly. Kaddoura and Husseiny (2023) offer one of the most comprehensive syntheses, categorizing barriers into technical, pedagogical, ethical, and equity dimensions. On the technical side, requirements for high-performance hardware (for example, advanced VR headsets and haptic devices) remain a significant cost barrier, while the heavy computational demands of immersive worlds place pressure on local devices and institutional IT resources.

Network infrastructure is another major constraint: reliable, low-latency broadband is essential for synchronous, multiuser experiences, yet bandwidth and connectivity limitations are common in many developing-country and rural contexts. Software complexity further complicates adoption, as creating, customizing, and maintaining pedagogically sound immersive content requires specialized development skills, sophisticated authoring tools, and ongoing platform updates. Taken together, these technical hurdles imply that without coordinated investment in devices, connectivity, and accessible development ecosystems, many institutions will struggle to realize the potential benefits of metaverse learning (Kaddoura & Husseiny, 2023).

Onggirawana et al. (2023) conducted a systematic literature review focused on distance-learning adaptations during the COVID-19 pandemic that relied on virtual educational spaces. Their synthesis shows that the pandemic did accelerate institutional interest in and experimentation with immersive and virtual platforms as alternatives to face-to-face instruction. However, the review also finds that moving from short-term emergency use to sustainable adoption presents major obstacles, not least because many institutions adopted virtual solutions without addressing the deeper structural issues that limit equitable access.

A central concern identified by Onggirawana et al. (2023) is digital equity: students from lower socioeconomic backgrounds faced disproportionate barriers to participating in virtual and immersive learning. These barriers include lack of reliable broadband, absence of personal devices capable of running immersive applications, limited quiet study space, and lower levels of digital literacy or support at home. Such constraints raise the risk that metaverse learning, if deployed without deliberate equity measures, could widen existing educational gaps rather than reduce them. For educational technologists, this digital equity dimension constitutes a critical ethical challenge, implying that responsible metaverse implementation must pair technological innovation with targeted policies for access, subsidized infrastructure, inclusive design practices, and community support mechanisms (Onggirawana et al., 2023).

Table 2. Key Challenges and Recommended Strategies for Metaverse Learning Implementation

Challenge Domain	Specific Challenges	Recommended Strategies
Technical	High hardware costs, bandwidth requirements, software complexity	Cloud-based metaverse solutions; device-agnostic platforms; open-source development
Pedagogical	Educator competency gap, limited metaverse-specific instructional design models	Comprehensive teacher training programs; community of practice models; curriculum integration frameworks
Equity & Access	Digital divide, socioeconomic disparities, disability accessibility	Universal Design for Learning integration; tiered access models; government subsidy programs
Privacy & Ethics	Biometric data collection, avatar identity, behavioral surveillance	Transparent data governance frameworks; opt-in data collection; ethical review processes
Assessment	Traditional assessment incompatibility, validation of immersive assessment methods	Authentic task-based assessment; portfolio approaches; multimodal evidence collection

Source*: Synthesized from Kaddoura & Husseiny (2023); Chamola et al. (2025); Illi & Elhassouny (2025)*

D. Metaverse Learning in the Educational Technology Practice Context

The synthesis of findings frames metaverse learning as a logical next step in educational technology's ongoing effort to harness transformative tools for pedagogy. Rather than representing an abrupt break with past innovations, the metaverse can be seen as an extension of earlier shifts, from programmed instruction to multimedia and online learning, that expand where, when, and how learning occurs. Mitra (2023) frames the metaverse as a virtual-physical ecosystem suited to innovative blended education, arguing that the most effective implementations will combine, not replace, face-to-face and virtual modalities. In this view, hybrid designs can exploit the sensory richness and interactivity of immersive spaces for experiential tasks while preserving the social, logistical, and emotional benefits of in-person instruction.

This blended approach resonates with established educational technology theory, especially constructivist and social learning perspectives that value learning through active experience and meaningful interaction (Wang et al., 2022). When thoughtfully integrated, metaverse components, simulations, collaborative virtual projects, and adaptive supports, can complement classroom activities by providing safe practice environments, differentiated pathways, and opportunities for broader collaboration. Realizing this potential requires careful alignment of learning objectives, assessment strategies, and access considerations so that hybrid models leverage the complementary strengths of both physical and virtual environments rather than duplicating or undermining them (Mitra, 2023; Wang et al., 2022).

Zaga (2023) demonstrates the particular promise of metaverse applications in engineering education by showing how immersive virtual environments allow learners to interact directly with complex three-dimensional systems, conduct controlled simulations, and collaborate in shared virtual laboratory spaces. These affordances enable students to visualize and manipulate components at scales and speeds that would be impractical, expensive, or unsafe in physical labs, and they support iterative experimentation and immediate feedback that deepen conceptual understanding. By recreating realistic engineering contexts, from assembly and testing to failure analysis, metaverse-based activities can bridge the gap between theoretical instruction and hands-on practice in ways that traditional classrooms and static digital resources cannot easily match.

Building on this, Nedeva et al. (2025) analyze how the metaverse uniquely cultivates a cluster of higher-order competencies for engineering students, including enhanced spatial reasoning, integrated systems thinking, and collaborative problem-solving under realistic temporal and resource constraints. Their work highlights that immersive scenarios force learners to coordinate across roles, manage interdependent subsystems, and negotiate tradeoffs in near-realistic conditions, thereby fostering skills that are central to professional engineering practice. Together, these studies imply that while metaverse learning can be applied across many disciplines, its pedagogical advantages are especially strong in domains that demand complex applied practice, where embodied interaction, dynamic simulation, and socially distributed problem solving produce meaningful gains in competence and readiness for real-world tasks (Zaga, 2023; Nedeva et al., 2025).

CONCLUSION

Metaverse learning represents a genuinely transformative paradigm for educational technology, offering demonstrated advantages in engagement, collaboration, and retention while presenting significant implementation challenges that require systematic attention. The Edu-Metaverse ecosystem framework, integrating immersive environments, collaborative spaces, and AI-powered adaptive learning, provides educational technologists with a coherent conceptual foundation for designing effective virtual learning experiences. Successful implementation requires multi-stakeholder collaboration, substantial investment in teacher professional development, commitment to digital equity, and robust ethical governance frameworks. Future research should prioritize longitudinal effectiveness studies, equity impact assessments, and the development of metaverse-specific instructional design models appropriate for diverse educational contexts.

REFERENCES

Bobko, T., Corsette, M., Wang, M., & Springer, E. (2024). Exploring the Possibilities of Edu-Metaverse: A New 3-D Ecosystem Model for Innovative Learning. IEEE Transactions on Learning Technologies, 17, 1290–1301.

https://doi.org/10.1109/tlt.2024.3364908
Chamola, V., Peelam, M. S., Mittal, U., Hassija, V., Singh, A., Pareek, R., Mangal, P., Sangwan, D., De Albuquerque, V. H., Mahmud, M., & Brown, D. (2025). Metaverse for Education: Developments, Challenges, and Future Direction. Computer Applications in Engineering Education, 33. https://doi.org/10.1002/cae.70018
Illi, C., & Elhassouny, A. (2025). Edu-Metaverse: A Comprehensive Review of Virtual Learning Environments. IEEE Access, 13, 30186–30211. https://doi.org/10.1109/access.2025.3540944
Kaddoura, S., & Husseiny, F. A. (2023). The Rising Trend of Metaverse in Education: Challenges, Opportunities, and Ethical Considerations. PeerJ Computer Science, 9. https://doi.org/10.7717/peerj-cs.1252
Lee, H., & Hwang, Y. (2022). Technology-Enhanced Education through VR-Making and Metaverse-Linking to Foster Teacher Readiness and Sustainable Learning. Sustainability. https://doi.org/10.3390/su14084786
Li, C., Jiang, Y., Ng, P., Dai, Y., Cheung, F., Chan, H., & Li, P. (2024). Collaborative Learning in the Edu-Metaverse Era: An Empirical Study on the Enabling Technologies. IEEE Transactions on Learning Technologies, 17, 1107–1119. https://doi.org/10.1109/tlt.2024.3352743
Mitra, S. (2023). Metaverse: A Potential Virtual-Physical Ecosystem for Innovative Blended Education and Training. Journal of Metaverse. https://doi.org/10.57019/jmv.1168056
Nedeva, V., & Dineva, S., & Atanasov, S. (2025). Engineering Education Meets the Metaverse. Acta Infologica. https://doi.org/10.26650/acin.1612225
Nedeva, V., & Ducheva, Z. (2024). Pedagogical Approaches for Metaverse-based Engineering Education. Proceedings of the International Conference on Virtual Learning (19th ed.). https://doi.org/10.58503/icvl-v19y202412
Onu, P., Pradhan, A., & Mbohwa, C. (2023). Potential to Use Metaverse for Future Teaching and Learning. Education and Information Technologies, 29, 8893–8924. https://doi.org/10.1007/s10639-023-12167-9
Onggirawana, C. A., Khoa, J. M., Kartiwaa, A. P., & Gunawana, A. (2023). Systematic Literature Review: The Adaptation of Distance Learning Process During the COVID-19 Pandemic Using Virtual Educational Spaces in Metaverse. Procedia Computer Science, 216, 274–283. https://doi.org/10.1016/j.procs.2022.12.137
Rahman, K., Shitol, S. K., Islam, M. S., Iftekhar, K. T., & Saha, P. (2023). Use of Metaverse Technology in Education Domain. Journal of Metaverse. https://doi.org/10.57019/jmv.1223704
Sidhu, M., Mousakhani, S., Lee, C. K., & Sidhu, K. (2024). Educational Impact of Metaverse Learning Environment for Engineering Mechanics Dynamics. Computer Applications in Engineering Education, 32. https://doi.org/10.1002/cae.22772
Sripan, T., & Jeerapattanatorn, P. (2025). Metaverse-based Learning: A Comprehensive Review of Current Trends, Challenges, and Future Implications. Contemporary Educational Technology. https://doi.org/10.30935/cedtech/16434
Ulusar, U., Ozel, D., Kursun, K., Bayraktar, M., & Gabdyssalyk, R. (2026). Evaluation of Metaverse as a Learning Environment and Level of Technology Acceptance: An Engineering Example. Journal of Computer Assisted Learning. https://doi.org/10.1002/jcal.70195
Villegas-Ch., W., Garcia-Ortiz, J., & Sanchez-Viteri, S. (2024). Educational Advances in the Metaverse: Boosting Learning Through Virtual and Augmented Reality and

Artificial Intelligence. IEEE Access, 12, 59093–59112. https://doi.org/10.1109/access.2024.3393776

Wang, M., Yu, H., Bell, Z., & Chu, X. (2022). Constructing an Edu-Metaverse Ecosystem: A New and Innovative Framework. IEEE Transactions on Learning Technologies, 15, 685–696. https://doi.org/10.1109/tlt.2022.3210828

Wang, Y., Lee, L.-H., Braud, T., & Hui, P. (2022). Re-shaping Post-COVID-19 Teaching and Learning: A Blueprint of Virtual-Physical Blended Classrooms in the Metaverse Era. 2022 IEEE 42nd International Conference on Distributed Computing Systems Workshops (ICDCSW), 241–247. https://doi.org/10.1109/icdcsw56584.2022.00053

Yeganeh, L. N., Fenty, N., Chen, Y., Simpson, A., & Hatami, M. (2025). The Future of Education: A Multi-Layered Metaverse Classroom Model for Immersive and Inclusive Learning. Future Internet, 17, 63. https://doi.org/10.3390/fi17020063

Zaga, F. A. R. (2023). Enhancing Interactive Learning in Engineering Education: Exploring the Metaverse's Virtual Horizons. 2023 World Engineering Education Forum – Global Engineering Deans Council (WEEF-GEDC), 1–6. https://doi.org/10.1109/weef-gedc59520.2023.10343748