

Volume 13 (2025), pp. 85-96
*American Journal of STEM Education:
Issues and Perspectives*
Star Scholars Press
<https://doi.org/10.32674/0h8z0j95>

AI and Immersive Technologies in International STEM Learning

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ABSTRACT

AI-powered immersive technologies, including virtual and augmented reality, reshape international STEM education by providing equitable, location-independent access to experiential learning and intercultural collaboration. This article examines their pedagogical value, implementation challenges, and strategies for fostering global engagement in STEM disciplines.

Keywords: AI, AR, equity, immersive learning, international students, STEM, virtual reality

INTRODUCTION

International education has traditionally been constrained by geographic boundaries, financial barriers, and stringent visa policies that limit student mobility (Mowreader, 2025). However, as the Fourth Industrial Revolution reshapes global labor markets and skills requirements, higher education institutions increasingly adopt technological innovations to further expand access and engagement, especially for students outside the United States, expanding their internationalization efforts (Torres & Statti, 2022; Chen et al., 2020). Among these innovations, recent advancements in immersive technologies such as virtual reality (VR) and augmented reality (AR), when integrated with artificial intelligence (AI),

offer new opportunities for international students by creating contextualized and simulated authentic learning environments (Torres & Statti, 2022).

VR and AR technologies allow international students to engage in immersive learning experiences without being physically present on campus. Through high-fidelity simulations and interactive virtual environments, learners from diverse global locations can collaboratively develop practical skills, explore complex concepts, and interact with peers in real time, mirroring the dynamics of multiplayer gaming platforms (Wang et al., 2023). This sense of immersion helps overcome the limitations of place-bound education, offering equitable access to high-quality instruction and participation in global academic communities for students who might otherwise face visa restrictions or financial constraints.

In STEM and other applied disciplines, where experiential learning is crucial, AI-driven VR and AR technologies represent a significant paradigm shift. Historically, the structural limitations of STEM education have excluded many from full participation in global academic networks (Torres & Statti, 2022). By building remote laboratory instruction models developed during the COVID-19 pandemic, institutions can extend these immersive innovations to international learners. Leveraging VR and AR, higher education can provide equitable, location-independent access to firsthand STEM education (Chng et al., 2023), democratizing access to critical educational pathways.

Immersive Learning and Its Pedagogical Foundations

Well-established pedagogical theories, constructivism, and experiential learning (Chen, 2009), underpin immersive learning technologies, particularly virtual reality (VR) and augmented reality (AR). These theories provide a robust foundation for understanding how immersive technologies can transform STEM education by promoting active, authentic, and collaborative learning experiences (Chen, 2009; Xu et al., 2022). Constructivist and experiential perspectives explain the pedagogical value of VR and AR and inform the systematic development and implementation of educational systems grounded in these technologies (Leung et al., 2018). By aligning immersive learning technologies with these theories, educators can leverage VR and AR to facilitate deeper conceptual understanding, increased engagement, and enhanced skill acquisition in STEM disciplines (Chen, 2009; Maroukas et al., 2023).

Constructivism posits that learners actively construct their understanding and knowledge of the world through experience and reflection rather than passively absorbing information (Chen, 2009). In this paradigm, learning is conceptualized as a dynamic and iterative process where students engage with content, manipulate variables, and interact with peers and environments to make sense of complex concepts (Veletsianos, 2010; Chng et al., 2023). Immersive

technologies such as VR and AR are particularly well-suited to operationalize constructivist principles. They provide interactive, context-rich environments in which learners can explore, experiment, and collaborate even when they are not physically co-located (Chen, 2009; Maroukas et al., 2023). For example, VR enables students to visualize abstract scientific phenomena, manipulate 3D models, and participate in simulated laboratory experiments. These experiences foster deeper conceptual understanding and critical thinking (Radianti et al., 2020; Familoni & Onyebuchi, 2024).

Experiential learning theory, as articulated by Kolb (1984), centers on the idea that knowledge is created through a cyclical process involving four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Immersive environments such as virtual reality (VR) and augmented reality (AR) enable students to engage in all stages of this cycle: They can have direct, hands-on experiences (concrete experience), reflect on outcomes and processes (reflective observation), formulate and test hypotheses (abstract conceptualization and active experimentation), and apply new knowledge in varied contexts (Kolb, 1984; Chen, 2009). Research demonstrates that VR and AR increase engagement and motivation and improve learning outcomes by allowing students to experience and reflect upon complex scenarios in safe, controlled, and repeatable settings (Aebersold et al., 2020; Chng et al., 2023; Xu et al., 2022).

Building on these pedagogical foundations, recent technological advancements have enhanced the accessibility, scalability, and pedagogical impact of immersive learning. The development of sophisticated yet increasingly affordable head-mounted displays, such as the HTC Vive and Oculus Rift, has accelerated the adoption of VR and AR in educational settings (Familoni & Onyebuchi, 2024; Radianti et al., 2020; ITIF, 2021). These technologies allow students to engage with interactive simulations, navigate complex systems, and manipulate virtual environments—practices that deepen conceptual understanding and foster discipline-specific skills. In STEM education, such affordances are transformative. VR and AR allow learners to visualize abstract data, conduct virtual experiments, and explore scientific phenomena that may be inaccessible through traditional instructional methods (Chen, 2009; Paraskevi et al., 2019).

The evolution of immersive learning is further propelled by the integration of artificial intelligence (AI). Recent advancements in generative AI have enabled the development of adaptive, personalized educational experiences within VR and AR environments (Wang et al., 2023). When integrated with immersive technologies, AI can assess individual learning preferences, deliver real-time feedback, and translate content across languages — enhancing accessibility and cultural relevance for international students and diverse learners (Nguyen et al., 2024; Javaid et al., 2023). This convergence of AI and immersive technologies supports differentiated instruction, fosters learner autonomy, and cultivates

intercultural competence—critical attributes for STEM professionals operating in an increasingly globalized and interconnected world (Wang et al., 2023; Xu et al., 2022). As a result, the synergy between experiential learning theory, technological innovation, and AI-driven personalization positions immersive learning as a transformative approach for advancing STEM education in local and international contexts.

Transcending Boundaries in Global STEM Access

AI-enhanced immersive technologies are reshaping international STEM education by removing traditional physical and geographic barriers. Through advanced VR and AR platforms, students across the globe can now participate in virtual laboratories, global field trips, and collaborative projects that were once limited to those physically present on campus (Wang et al., 2023; Chen, 2009). These technologies enable international students to access the same high-quality, interactive STEM experiences as their peers in the United States, promoting equitable participation and engagement regardless of location. The ability to join virtual simulations, manipulate scientific instruments, and collaborate with classmates in real-time ensures that learners outside the U.S. are no longer disadvantaged by distance or restrictive visa policies (Information Technology and Innovation Foundation, 2021; Torres & Statti, 2022).

The pedagogical power of immersive environments lies in their capacity to create a strong sense of presence. Presence—the psychological perception of “being there” in a virtual space—is associated with emotional and cognitive engagement (Bernate & Vargas, 2024; Strivr, 2024). This immersive quality is especially valuable in cross-cultural and international contexts, where students can virtually explore global cities, participate in cultural rituals, or engage in realistic simulations of international engineering, environmental, or public health scenarios. These experiences deepen subject-matter understanding and promote empathy, intercultural awareness, and global competence—skills increasingly essential for STEM professionals in a connected world (Bernate & Vargas, 2024; Training Industry, 2024).

Integrating artificial intelligence within immersive environments further personalizes and enriches these borderless learning experiences. AI-driven features such as real-time translation and content localization enhance the accessibility of immersive learning environments for international students. These tools ensure that learners from diverse linguistic and cultural backgrounds can fully engage with course materials, participate in collaborative activities, and access high-quality STEM instruction regardless of geographic location (Wang et al., 2023; Nguyen et al., 2024).

By leveraging these capabilities, educators can implement differentiated instruction and foster inclusive, collaborative learning communities that transcend national boundaries. In doing so, immersive learning becomes a tool

for academic engagement and a vehicle for global equity and inclusion in STEM education.

Intercultural and Language Learning

Developing intercultural competence is a critical objective in international STEM education, where collaboration across cultural and linguistic boundaries is increasingly necessary for both professional and academic success in international contexts (Chen, 2009). Immersive learning technologies, particularly virtual reality (VR) and augmented reality (AR), offer unique opportunities to simulate culturally nuanced environments, enabling students to “experience” diversity in authentic contexts (Rutledge et al., 2020). These technologies enable learners to engage in scenarios such as culturally sensitive negotiations, participation in multilingual teams, and exploration of socio-technical challenges in global settings, all within a safe and controlled environment (Rutledge et al., 2020).

Research demonstrates that VR and AR can potentially enhance intercultural competence and openness by providing students with direct, immersive contact with diverse cultures (DeWitt et al., 2022; Li et al., 2021). For example, VR-based simulations have improved learners’ cognitive and affective domains of intercultural competence, including respect, openness, curiosity, and discovery (DeWitt et al., 2022). Similarly, AR platforms facilitate intercultural exchanges by enabling learners from diverse backgrounds to share narratives and collaboratively explore cultural content, fostering confidence and enthusiasm for cross-cultural engagement (Sabie et al., 2023).

Language development is a key component of this intercultural learning process. For international students in STEM fields, mastering the language of instruction and professional discourse is crucial. VR and AR environments offer realistic, context-rich opportunities to practice communication skills in discipline-specific settings—such as virtual labs, technical discussions, or collaborative design tasks (Gracia, 2024; Liu et al., 2016). These experiences enhance language proficiency and foster pragmatic and cultural fluency, enabling students to navigate the social and communicative norms of STEM fields.

Artificial intelligence (AI) enhances immersive learning environments by enabling personalized, responsive, and culturally adaptive educational experiences. Within virtual reality (VR) and augmented reality (AR) platforms, AI can analyze learner interactions, deliver adaptive feedback, and tailor content to individual needs—supporting the development of empathy, reducing cultural bias, and fostering intercultural fluency (Nguyen et al., 2024; Wang et al., 2023). These capabilities are particularly valuable for international students in STEM fields, who benefit from real-time language translation, scenario customization, and culturally relevant instructional design. By aligning immersive content with learners’ linguistic and cultural backgrounds, AI-driven systems increase both

accessibility and relevance, helping students engage more deeply with STEM material (Wang et al., 2023). However, integrating AI into educational technologies raises important ethical considerations. Issues such as algorithmic bias, cultural misrepresentation, and data privacy must be addressed to ensure these tools promote inclusion rather than reinforce inequities (Mendoza et al., 2023). When implemented responsibly, the convergence of VR, AR, and AI offers a robust framework for embedding intercultural training and language development into the core of STEM education, preparing international students not only to succeed academically but also to participate effectively in a globalized, multicultural workforce (Rutledge et al., 2020; Wang et al., 2023).

Challenges and Ethical Considerations

While immersive learning technologies, such as virtual reality (VR) and augmented reality (AR) hold significant promise for democratizing access to high-quality STEM education for international students, several challenges hinder their equitable implementation. The high cost of VR headsets and the resource-intensive nature of content development remain substantial barriers, particularly for institutions and learners in underserved regions (Calvet et al., 2019; Youngblut, 1998). Infrastructure limitations, including inadequate internet bandwidth and limited access to high-performance computing, further exacerbate these disparities (Calvet et al., 2019; XR in Higher Education, 2024). Digital literacy gaps among students and faculty can marginalize those unfamiliar with emerging technologies, reinforcing existing educational inequities (EON Reality, 2024; Center Forward, 2024).

The integration of AI into immersive learning environments raises important ethical concerns. The collection and analysis of behavioral patterns to biometric data for personalization risks privacy, surveillance, and algorithm bias (Edly, 2025; Wang et al., 2023). Without transparent governance and culturally sensitive design, AI systems may inadvertently reinforce stereotypes or exclude marginalized learners (Edly, 2025; Mendoza et al., 2023). Authentic community input must guide the design of culturally immersive simulations to prevent the reinforcement of stereotypes or misrepresentation of cultural identities (Mendoza et al., 2023). Institutions must implement robust data protection protocols and ensure that AI tools are developed and deployed with ethical oversight.

Finally, the physical and cognitive safety of learners must be considered. Users may experience motion sickness, cognitive overload, or ergonomic discomfort, especially during extended sessions or when using poorly designed systems (Calvet et al., 2019; Center Forward, 2024; XR in Higher Education, 2024). Addressing these challenges requires a collaborative, multidisciplinary approach that balances innovation with ethical responsibility, prioritizes equitable

access, and continuously evaluates the impact of immersive technologies on diverse learner populations (Frontiers in Virtual Reality, 2024; Partarakis & Zabulis, 2024)

Strategies for Scalable Implementation

To fully realize the potential of immersive learning technologies in delivering equitable STEM education across borders, higher education institutions must adopt strategic, equity-centered approaches that address access and instructional quality. Leveraging low-cost augmented reality (AR) tools compatible with widely available mobile devices, implementing cloud-based virtual reality (VR) platforms, and developing open-access immersive content are key strategies for reaching students in diverse global contexts (Chen, 2009; Calvet et al., 2019; Activate Learning, 2024). Open-source educational resources and collaborative content development initiatives can further democratize access, ensuring that students in underserved regions benefit from the same high-quality learning experiences as their peers in more resourced environments (Activate Learning, 2024; Mohammadi et al., 2019).

Institutional investment in faculty development and international collaboration is equally critical. Comprehensive teacher training, global partnerships, and the sharing of effective pedagogical practices can enhance the integration of VR and AR in STEM instruction. Virtual exchange programs that incorporate immersive experiences enable students from different countries to engage in shared simulations, co-create solutions to global challenges, and develop intercultural competence (Nguyen et al., 2024; Rutledge et al., 2020). Integrating AI-powered adaptive feedback and personalized learning scenarios within these programs can further enrich educational outcomes and foster deeper engagement (Nguyen et al., 2024).

To ensure the effectiveness and sustainability of these initiatives, institutions should implement robust assessment frameworks that track learning outcomes, intercultural competence, and student engagement (Chen, 2009; Wang et al., 2023). Ongoing evaluation, participatory instructional design, and iterative refinement—such as those outlined in the Virtual Reality Instructional Design (VRID) model, which emphasizes learner-centered, feedback-driven development of immersive content—can help tailor immersive learning environments to the needs of international STEM students while upholding ethical standards (Chen, 2009; Calvet et al., 2019). By embracing these strategies, higher education can scale immersive technologies to deliver borderless, high-impact STEM education for learners worldwide.

Conclusion

Immersive learning technologies, particularly virtual and augmented reality enhanced by artificial intelligence, reshape the STEM education landscape for international and remote learners. Grounded in constructivist and experiential learning theories, these tools provide students across diverse global contexts with access to high-quality resources, collaborative experiences, and authentic simulations that mirror those available to peers in more resourced environments (Chen, 2009; Wang et al., 2023). Recent advancements in VR and AR hardware and AI-driven personalization have made it possible to transcend physical and linguistic boundaries, foster intercultural competence, and support language development through interactive, context-rich environments (Nguyen et al., 2024; Rutledge et al., 2020).

While challenges related to cost, infrastructure, digital literacy, and ethical concerns remain, strategic implementation and continuous evaluation can help mitigate these barriers. Equity-driven approaches—such as leveraging low-cost technologies, promoting open-access content, and ensuring culturally responsive design—are essential to the global scaling of immersive learning (Calvet et al., 2019; Mendoza et al., 2023). As immersive technologies continue to evolve, they hold the potential to make international STEM education more inclusive, adaptive, and practical, empowering learners worldwide to thrive in an increasingly interconnected and technologically advanced world.

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