AI AND VR AS ARCHITECTURES OF INCLUSIVE LEARNING ECOSYSTEMS: REDESIGNING EDUCATION THROUGH UNIVERSAL DESIGN FOR LEARNING 3.0

AI E VR ARCHITETTURE DI SPAZI INCLUSIVI: RIPROGETTARE L'APPRENDIMENTO ATTRAVERSO L'UNIVERSAL DESIGN FOR LEARNING 3.0

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ABSTRACT

The Universal Design for Learning (UDL) 3.0 guidelines emphasize the uniqueness of each learner and the variety of learning styles, highlighting the role of digital technologies in supporting inclusive education (CAST, 2024). This study, through a review of the existing literature, explores how the integration of Artificial Intelligence (AI) in Virtual Reality (VR) environments enables immersive and adaptive learning experiences. These experiences align with the principles of UDL 3.0, contributing to a more equitable, accessible, and personalized educational approach.

Le linee guida dell'*Universal Design for Learning* 3.0 (UDL) pongono al centro l'unicità dello studente e le differenti modalità di apprendimento, evidenziando l'apporto dei sistemi digitali (CAST, 2024). Lo studio proposto, attraverso la revisione della letteratura, evidenzia come l'integrazione dell'Intelligenza Artificiale (AI) in ambienti di realtà virtuale (VR) favorisca esperienze immersive e adattive, rispondendo ai principi dell'UDL 3.0 e rendendo l'apprendimento più equo, accessibile e personalizzato.

KEYWORDS

Virtual reality, UDL, artificial intelligence, inclusion, learning environment
Realtà virtuale, UDL, intelligenza artificiale, inclusione, ambiente di apprendimento

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Introduction

The digital transformations that have profoundly affected contemporary society since the early 2000s have been progressively acknowledged by European policies and, specifically, by Italian ones through the promulgation of various strategic documents. Initially conceived in instrumental terms, digital technology has gradually acquired pedagogical and didactic relevance, becoming a foundational component of educational processes (Limone, 2021). In this direction, the European Parliament, with its 2006 Recommendation—later updated in 2018—included digital competence among the eight key competences essential for citizens in a lifelong learning perspective. Aligned with this vision, the European Commission launched the Digital Education Action Plan (2021–2027), emphasizing the need to adapt educational systems to ongoing digital transformations. The Italian context has followed a similar trajectory, as evidenced by measures within the National Recovery and Resilience Plan (PNRR) and, in particular, the "Piano Scuola 4.0" issued through Ministerial Decree No. 161 on 14 June 2022. These regulatory instruments highlight the reorganization of school environments and the creation of flexible, technologically advanced spaces capable of addressing the challenges posed by the digital transition.

On one hand, artificial intelligence is now at the center of pedagogical, technical, and ethical reflection aimed at exploring its impact on instructional design and the personalization of educational pathways. On the other hand, over the past decade, immersive technologies—particularly virtual reality—have proven to be tools capable of redefining educational processes by transforming the student's role from passive recipient to active participant. These changes occur within a pedagogical-didactic landscape undergoing profound transformation, marked by the gradual abandonment of standardized models and by a vision of education centered on diversity and the uniqueness of each learner. At the same time, the educational system is called upon to face increasingly complex challenges—not as a result of these pedagogical-didactic changes — but in response to the growing heterogeneity of students, the rapid pace of digital transformation, and the necessity to promote equitable and inclusive learning environments.

Within this framework, the need emerges for instructional design that can acknowledge and value individual differences, responding flexibly to diverse cognitive and learning styles, as well as to special educational needs.

In this context, the Universal Design for Learning (UDL) 3.0, updated in July 2024, offers an effective theoretical-operational response for guiding inclusive instructional design (CAST, 2024). The guidelines are based on three core principles: 1) Engagement; 2) Representation; 3) Action and Expression. Compared to the 2018 version, the 2024 update introduces significant innovations, including the enhancement of student identity as an active subject and the structural need to overcome biases, exclusions, and inequalities. A central element of the framework is the transformative role attributed to technologies. While in the 2018 version they were primarily seen as compensatory tools aimed at promoting accessibility, the 3.0 update recognizes digital technologies as didactic, cultural, and social mediators capable of transforming and enhancing learning experiences (Savia, 2016; Sgambelluri, 2023). Personalization thus becomes a structural component of both instructional design and the educational environment. This orientation draws inspiration from the principle of Design for All, which advocates for an anticipatory instructional design that can address differences from the initial planning stages, thereby surpassing adaptive logics (De Angelis, 2025).
The integration of artificial intelligence and virtual reality represents an opportunity to reconceptualize school as an immersive educational ecosystem, where body, mind, environment, and technology interact to generate situated learning. On the one hand, AI, with its ability to analyze large datasets, appears capable of providing personalized feedback, promoting self-regulation, and supporting adaptive learning pathways. On the other hand, VR, through its immersive quality, allows for the embodied and symbolic experience of content, fostering deep and multisensory understanding. When employed within an educational-didactic framework that values each student's uniqueness, AI and VR seem to contribute to the construction of truly inclusive learning environments.

1. Immersive technologies for motivating, engaging, and participatory learning

Over the past decade, immersive technologies such as Virtual Reality (VR) have increasingly played a potentially significant role in the educational domain, promoting, under certain conditions, experiential and participatory forms of learning. VR is applied both within constructivist pedagogical models—focused on the interaction between the individual, content, and environment—and within cognitivist perspectives, due to its capacity to potentially deliver flexible, adaptive, and personalized content. Unlike traditional media, VR is characterized by a high level of immersivity, made possible through the use of personal headsets and the ability to explore three-dimensional digital environments.

Consistent with the first principle of Universal Design for Learning 3.0 (UDL), “design multiple means of engagement,” immersive technologies may activate students’ interest, motivation, and curiosity, supporting different educational needs and diverse learning styles (CAST, 2024; Rossi & Toto, 2024).

Recent studies suggest that the integration of artificial intelligence into virtual environments can foster meaningful and situated learning experiences, enhancing students’ attention and intrinsic motivation while potentially promoting engagement (Le Corre & Huang, 2024; Shirazi et al., 2024). In particular, the synergy between VR and AI might enhance student involvement, potentially reinforcing autonomy, and encouraging active participation. These findings align with UDL checkpoints 7.1 “optimize choice and autonomy” and 7.2 “optimize relevance, value, and authenticity,” which emphasize the importance of providing dynamic educational environments oriented toward the development of learner identity.

Immersive technologies also lend themselves to supporting the implementation of gamification strategies—such as badges, points, challenge levels, and collaborative missions—which can activate playful dynamics that might stimulate commitment and strengthen self-efficacy (Finestrone et al., 2023; Sgambelluri, 2023). In this way, learning takes place within a ludic-educational context in which experimentation is an integral part of the learning process. These approaches reflect the logic of edutainment, where enjoyment is not the end goal but a tool that can stimulate motivation, facilitates access to complex content, and supports meaningful learning (Guarini et al., 2022). The ludic and emotional dimension aligns with UDL 3.0, particularly with checkpoint 7.3 “nurture joy and play,” potentially contributing to the construction of educational environments in which pleasure, curiosity, and discovery are structural components of the educational process.

AI-VR technologies, when integrated into inclusive instructional design, might also contribute to clarifying learning goals and evaluation criteria (Shirazi et al., 2024). In this way, students may engage with authentic tasks and receive immediate and formative feedback aimed at supporting continuous improvement (Finestrone et al., 2023). This adaptive capacity aligns with UDL checkpoints 8.1 “clarify the meaning and purpose of goals” and 8.5 “offer action-oriented feedback”.

Moreover, AI-VR generated environments, by replicating real-life situations, might support collaborative dynamics and positive interdependence, enabling, under certain conditions, peer interaction, stimulating social engagement, and fostering the co-construction of knowledge (Järvenoja et al., 2020; Rossi et al., 2023). In this regard, immersive learning aligns with checkpoints 8.3 "foster collaboration and community" and 8.4 "foster belonging and community".

The use of immersive technologies in education requires the development of specific professional skills in instructional planning and assessment, as the teacher plays a key role in selecting virtual environments and fostering students' media competencies. Students must be equipped to use artificial intelligence effectively within their learning processes (Scarano & Ferrantino, 2024).

The correlation between emotional dimension and digital content is an aspect often overlooked by teachers during instructional design and implementation. In fact, the quality of the user experience (UX) plays a central role in designing immersive learning environments. It is no longer sufficient to assess the mere technical functionality of tools; rather, it is necessary to consider how students interact with the digital environment and how such interaction influences intrinsic motivation and the construction of meaning (Muscarà et al., 2024). The intentional use and repeated engagement with a multimedia product are strongly influenced by ease of use and perceived usefulness—elements related to experiential design principles (Makkan et al., 2020). UX encompasses both pragmatic components—related to functionality and efficiency of use—and hedonic components, which satisfy emotional and psychological needs. Both are crucial in designing digital learning environments that combine accessibility, engagement, and the meaningfulness of the educational experience (De Luca, 2016). The user experience design approach places the experiential dimension at the center, shifting the focus from operational efficiency to the user's emotional engagement (Thielsch et al., 2019). Within this framework, emotional technologies—digital tools designed to interact with the affective dimensions of learning—highlight the importance of psychological variables (e.g., enjoyment, motivation, attention) in shaping users' educational experience with technology (Muscarà et al., 2024). A notable example is represented by modern VR headsets equipped with eye-tracking, facial recognition, and wireless technologies, which can significantly enhance the quality and naturalness of user-environment interaction. In this direction, research on affective learning analytics is also developing, enabling dynamic adaptation of learning pathways to the psychological conditions of each learner by using biometric sensors

to detect and interpret emotional states during instructional activities (Prastawa et al., 2019).
Since the protected and controlled nature of virtual environments might facilitate emotional regulation and the sense of belonging—thus potentially promoting the development of emotional competence (Saborío-Taylor & Rojas-Ramírez, 2024)—immersive technologies can be seen as effective inclusive educational tools aligned with UDL checkpoints 9.1 "recognize expectations, beliefs, and motivations," 9.2 "develop awareness of self and others," 9.3 "promote individual and collective reflection," and 9.4 "cultivate empathy and restorative practices" (CAST, 2024).
From this perspective, a new configuration of digital pedagogy emerges, in which the student is not merely a content recipient but may become an active protagonist of the learning process, and in which immersive technologies act as tools that can enhance engagement and active participation—of both the many and the individual (Barca et al., 2024).

2. Multiplicity of Languages and Accessibility: Representation for Inclusion

The introduction of artificial intelligence in the educational field has the potential to generate significant changes in teaching and learning processes as well as in the school environment (Forese, 2025).
Generative technologies, such as language models based on Generative Pre-trained Transformers, might be configured as Virtual Learning Environments (VLEs), potentially supporting both multidisciplinary and transdisciplinary educational pathways. VLEs not only may facilitate access to information but also might foster greater interconnection between bodies of knowledge, possibly promoting the integration of heterogeneous perspectives in solving complex problems and in the development of critical thinking (Chan & Tsi, 2023). This approach aligns with the second principle of UDL— "design multiple means of representation"—which emphasizes the need to diversify the ways in which students access, understand, and rework information (CAST, 2024).
In this regard, the synergy between AI and VR could be strategic, as the former allows may allow for dynamic adaptation of content formats (text, audio, transcription, images), offering potentially personalized versions according to levels of complexity, while the latter introduces a spatial and immersive dimension that

might enables the exploration of concepts in a multisensory and interactive way (Rossi et al., 2023; Fiorucci & Bevilacqua, 2024).
The integration of artificial intelligence and virtual reality might align various checkpoints under the second principle, namely: 1.1 “support opportunities to customize the display of information,” 1.2 “support multiple ways to perceive information,” and 2.5 “illustrate through multiple media.” Indeed, the personalization of information and the use of multimedia may be particularly effective for students with sensory and/or intellectual disabilities, who can benefit from alternative representations to construct knowledge in an accessible and participatory manner (Saborío-Taylor & Rojas-Ramírez, 2024; La Manna et al., 2024). In this regard, Cottini maintains that «l’orientamento dev’essere quello di costruire contesti in grado di accogliere tutti e consentire a ognuno di avere le migliori opportunità per raggiungere il successo formativo» (Cottini, 2017, p. 81). This principle might be reflected in educational practices such as the creation of simulations, intercultural scenarios, and narratives that include content aimed at valuing linguistic, historical, and cultural diversity. Such practices could potentially align with checkpoints 1.3 “Represent a diversity of perspectives and identities in authentic ways,” 2.1 “clarify vocabulary, symbols, and language structures” and 2.3 “cultivate understanding and respect across languages and dialects.” However, the risk of reproducing linguistic and cultural stereotypes embedded in AI models highlights the necessity for careful teacher oversight in order to promote the development of critical thinking in content management and ensure the achievement of UDL checkpoint 2.4 “address biases in the use of language and symbols” (Ranieri, 2024).
Within the broader discourse on AI, intelligent tutoring systems (ITS) represent a potential opportunity to ensure adaptive educational interventions that respond to students’ needs and aligned with the input they produce (Panciroli & Macauda, 2021). ITS may play a key role in achieving UDL checkpoint 3.1 “connect prior knowledge to new learning,” as they enable the activation of students' prior knowledge, paving the way for the restructuring of new understanding. Furthermore, AI-based tutoring systems might support students in understanding the relationships between concepts by offering diverse ways of reprocessing knowledge, possibly building meaning according to individual cognitive styles, and promoting transversal skills such as critical and divergent thinking (Nalbant & Aydin, 2024), in alignment with checkpoints 3.2 “highlight and explore patterns, critical

features, big ideas, and relationships," and 3.3 "cultivate multiple ways of knowing and making meaning."

3. Situated Learning and Expressive Multimodality Across Embodiment, Cognition, and Adaptive Digital Environments

The third principle of UDL 3.0 — "design multiple means of action and expression"—suggest the need to position the student as the protagonist in expressive and communicative choices, potentially enabling them to act through their own knowledge and sustain a level of awareness regarding their personal learning experience (Augenti, 2025).

Within the paradigm of enactive learning, which proposes learning as a process arising from the dynamic interaction between subject, body, and space, virtual environments, as Gallagher and Lindgren argue: «in essence, these mixed reality technologies may allow students to become part of the system they are trying to understand, giving them an 'insider' perspective on the critical mechanisms and relationships that define the domain» (Gallagher & Lindren, 2015, p. 399). From this perspective, knowledge is not simply transmitted but may be co-constructed through meaningful, embodied, and contextualized experiences, in a continuum of relationships involving the cognitive, affective, and symbolic dimensions of the human being (Carlomagno et al., 2021; Barca et al., 2024).

Adaptive and immersive technologies represent a potential resource because they entail physical interaction within digital spaces. Even in virtual environments, the student, through the use of headsets and controllers, can interact using gestures, posture, and manipulative actions. This mode can enable the experiential embodiment of disciplinary content, in line with the principles of constructivist pedagogy and embodied learning (Gomez-Paloma et al., 2016), potentially fulfilling the objectives identified in checkpoints 4.1 "vary and honor the methods for response, navigation, and movement" and 4.2 "optimize access to accessible materials and assistive and accessible technologies and tools." It is within this hybrid space—where the body interacts with the digital and learning becomes embodied—that a truly inclusive education might be constructed, grounded in the teacher's design responsibility and the valorization of diversity.

This aspect is also addressed in checkpoints 5.1 "use multiple media for communication," 5.2 "use multiple tools for construction, composition, and creativity," and 5.3 "build fluencies with graduated support for practice and performance." In this regard, it is important to distinguish between personalization, understood as the intentional design of flexible and inclusive instructional approaches that respond to learners' preferences, interests, and learning styles, and individualization, which involves specific interventions tailored to the needs of students with learning difficulties or special educational needs (Ianes, 2015).

Some tools, such as adaptive technologies or avatars, may serve both purposes depending on whether they are employed as universal supports or as compensatory strategies for individual learners. Indeed, the physical dimension may also be enhanced in cases where communication takes place through personalized avatars, which could allow for the representation of individual uniqueness, potentially improving participation in the learning process and contributing to the overcoming of stereotypes (Barca et al., 2024) (checkpoint 5.4 "address biases related to modes of expression and communication").

A central aspect of UDL 3.0 relates to executive functions—students' abilities to plan, monitor, and regulate their own learning process. AI, through real-time analysis of student inputs, may provide immediate and personalized feedback, potentially fostering the development of metacognitive skills such as self-regulation, self-assessment, critical and strategic thinking, and planning abilities. These skills are explicitly referred to in checkpoints 6.1 "set meaningful goals," 6.2 "anticipate and plan for challenges," 6.3 "organize information and resources," and 6.4 "enhance capacity for monitoring progress." Moreover, the ability to assess one's individual capabilities might enhance students' sense of self-efficacy, potentially encouraging them to view mistakes as an integral part of the learning process and to develop a resilient attitude typical of the growth mindset (Holmes et al., 2019; Rong et al., 2022).

Conclusions

The synergy between artificial intelligence and virtual reality could significantly contribute to the evolution of educational practices, potentially influencing not only the tools employed but also the ways in which teaching and learning processes are designed, mediated, and implemented. This transformation might help to redefine contemporary educational paradigms, understood as the set of theoretical and methodological frameworks that guide instructional practice, and could promote the development of inclusive learning environments in alignment with the principles of Universal Design for Learning 3.0. Multisensory interaction, three-dimensional simulation, and automated linguistic mediation may help to reconceptualize learning contexts as adaptive ecosystems in which learning might occur in a more situated, embodied, and relational manner. Within this scenario, it may become possible to design personalized educational pathways centred on the student and oriented toward the development of metacognitive skills. Such an approach would appear to align with the perspectives of situated learning, embodied cognition, and generative educational practices (Gomez-Paloma et al., 2016).

Recent developments in the construction of immersive environments seem increasingly guided by user experience criteria and are progressively intertwined with the integration of artificial intelligence systems. Italian educational policies may be moving in a similar direction, emphasizing the central role of the learning environment. Not coincidentally, the Piano Scuola 4.0 includes among its objectives the potential design of hybrid learning spaces, such as immersive laboratories. Indeed, «The physical learning environment of the 'classroom' must be designed and implemented in an integrated way with the digital learning environment, so that the transformed classroom also has access to a learning platform, ranging from an e-learning platform to a virtual reality platform that reproduces the physical environment of the class» (MIM, 2022, p. 26).

In this context, both initial and in-service teacher training would seem to play a crucial role, as teachers may be required to manage not only technological tools but increasingly complex learning environments. It becomes essential, then, that educators develop critical awareness and design competencies in order to manage technological integration effectively and to leverage its potential for transformation—particularly for students with special educational needs or those in vulnerable conditions.

Generative technologies, such as AI chatbots, could serve as valuable tools for teachers by offering support in the creation of customizable simulations, engaging activities, and the design of realistic learning scenarios. The ability of these systems to provide immediate and contextualized feedback may open up new possibilities for fostering critical and divergent thinking, as well as improving problem-solving skills, thus contributing to a potentially more engaging and inclusive learning experience (Scarano & Ferrantino, 2024). However, the effectiveness of generative systems in the teaching process appears to depend heavily on the quality of instructional design: in the absence of clear alignment among objectives, tasks, and assessment strategies, even the most sophisticated environments might result in superficial and ineffective learning (Baskara, 2023).

From this perspective, the emerging scenario may be situated within the broader paradigm of post-digital education (Castañeda & Selwyn, 2018), conceived as the deliberate construction of intelligent, adaptive, and context-sensitive learning environments. The integrated management of both physical and digital spaces within the school system could ensure more equitable access to emerging technologies, thereby helping to reduce inequality and to enhance the inclusive potential of AI- and VR-mediated educational experiences.

Nonetheless, significant concerns remain. As Maria Ranieri (2024) points out, the use of artificial intelligence raises important questions regarding student data privacy and the risk that educational relationships might be diminished or partially replaced by human-machine interaction, with potentially negative consequences for socio-emotional development. Moreover, prolonged exposure to highly stimulating virtual environments could lead to cognitive overload in students, thereby compromising the quality of learning outcomes (Makransky & Lilleholt, 2018). If not critically addressed, these challenges may undermine the inclusive and transformative promise of emerging technologies.

The convergence of AI and VR, when interpreted through the lens of UDL, would seem to support a vision of learning as a situated, participatory, and relational process, potentially fostering self-determination and academic success. The goal, therefore, would not be to replace educational relationships with generative systems, but rather to enhance them—placing the student at the center and valuing their identity, needs, and potential. Educational design, in this light, may serve to promote inclusive processes and active participation. Universal Design for Learning 3.0, then, may be regarded not only as an operational model but as a forward-looking ethical and design-oriented framework for the future of education, grounded in the synergy between technological innovation and the centrality of educational relationships.

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