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Social participation and epistemic autonomy in extended reality learning

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Abstract
This paper develops a normative account of the metaverse as a hybrid and pedagogically relevant form of Extended Reality (XR), thereby foregrounding the social, cognitive, and collaborative dynamics that shape virtual learning environments. Instead of locating its educational value in mere immersive simulation, the paper argues that the metaverse's normative didactic potential lies in its capacity to enable equitable participation, distributed cognition, and cross-border interaction among diverse learners. Addressing contemporary challenges—such as algorithmic personalization, filter bubbles, commercial biases, and avatar-mediated identity formation—the paper develops a normative framework for designing XR learning spaces that support epistemic autonomy while ensuring accessibility, inclusivity, and psychological safety. A special focus is on avatars as embodied interfaces that promote representation, interaction, and collective knowledge building. The paper concludes by outlining design principles for socially responsible XR environments that promote didactic participation across varied educational contexts.

Keywords Metaverse, Extended Reality, Digitization, Learning space, Virtuality, Avatar

1 Beyond immersion: the metaverse as a hybrid space of educational interaction

In 2022, Meta advertised its latest product in a video with the following slogan: "The Metaverse May Be Virtual, But the Impact Will Be Real."[1] In this context, Meta praises the potential and real benefits of this new technology: "[I]n the metaverse, we will be able to learn in 3D — bringing the study of architecture, history or even basic geometry to life in ways white boards and flat screens can't. There are also endless possibilities for training healthcare professionals—from practising surgery in virtual environments to training first responders without putting them in dangerous situations." The video shows how science students in a lecture hall are fascinated by a gigantic simulated cell fed to them by a teacher. What is striking about the quoted slogan is that the metaverse "may be virtual," which implies that it is to be only understood as an immersive simulation, although the effects of this immersion are certainly didactically "real" and significant.

[1] https://about.fb.com/news/2022/09/the-metaverse-may-be-virtual-but-the-impact-will-be-real/ (accessed 5/29/2025).

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The opening example can thus be read as a vignette that encapsulates a dominant but limited understanding of Extended Reality (XR)-based learning that equates virtuality with simulation. In what follows, this paper critically revisits this framing by examining how XR environments function not merely as representational tools but as socially and cognitively structured spaces of interaction. The initial contrast between the "virtual" and the "real" will therefore serve as a guiding motif, allowing us to demonstrate why such a dichotomy fails to capture the full pedagogical potential of the metaverse.

At the same time, this conceptual reframing responds to a set of concrete societal and educational challenges that have become increasingly visible with the emergence of the metaverse. These include the growing influence of algorithmically curated learning environments, the formation of epistemic silos through personalization and filter bubbles, the commercialization of digital infrastructures, and persistent inequalities in access to immersive technologies. In educational practice, such developments raise urgent concerns regarding epistemic autonomy, i.e., self-determination in technical-virtual environments, equitable participation, and the integrity of collaborative learning processes. By explicitly situating the analysis within these challenges, the paper clarifies why a normative design framework is needed and for whom it is intended—namely educators, institutions, and designers seeking to shape XR environments as socially responsible and pedagogically meaningful learning spaces.

Therefore, the core argument of this paper is that the educational value of the metaverse lies not in simulation, but in interaction, collaboration, and distributed cognition [1]. In this context, distributed cognition refers to the process by which cognitive activity is not confined to individual minds but extends across multiple agents, artifacts, and environments. Knowledge is thus not merely internally represented but emerges through coordinated interaction with external structures and other participants without just being simulated. Closely related, embodied cognition [2] emphasizes that cognitive processes are grounded in bodily action, perception, and situated engagement with the environment. Within XR settings, these perspectives jointly highlight that learning unfolds through spatialized interaction, avatar-mediated embodiment, and the interaction with shared virtual objects. By explicitly linking these concepts to established research traditions, the paper situates its analysis within a broader interdisciplinary discourse on cognition, responsibility, and learning.

Although the metaverse is often portrayed in public discourse as a highly immersive form of digital simulation, such a characterization is insufficient for understanding its educational potential. From a pedagogical perspective, the metaverse is more accurately conceived as a modality of Extended Reality (XR)—a hybrid space in which physical, digital, and social dimensions of learning converge. XR does not merely enhance perception through visual or sensory augmentation; it creates new modes of interaction, collaboration, and shared meaning-making. This becomes particularly evident in learning environments: learners do not operate within a simulated scenario that merely imitates the external appearance of reality, but within a relational space in which they jointly explore content, coordinate with one another, manipulate knowledge objects, and communicate in real time. The educational significance of the metaverse thus arises not from its immersive aesthetics but from its capacity to expand learning beyond the limitations of physical settings and to enable new forms of participation, presence, and collaborative inquiry.

To make this analytical trajectory more explicit, the paper draws selectively on established research traditions that conceptualize learning as socially and materially distributed processes. In particular, it aligns with work in distributed cognition [1], socio-constructivist learning theory, and media-theoretical accounts of communicative environments [3]. These frameworks are not treated as competing explanatory models but as complementary perspectives that converge on a shared insight: that cognition, learning, and meaning-making are structurally embedded in interactional, technological, and spatial configurations. The following sections therefore develop the argument by progressively integrating these traditions into a coherent normative account of XR-based learning.

Against this background, the paper is guided by three interrelated analytical questions: (1) How should XR and the metaverse be conceptually understood in order to avoid reduction to immersive simulation? (2) Under which social, cognitive, and normative conditions can XR environments function as genuine educational spaces? (3) What design principles follow from this analysis for socially responsible and autonomy-supporting XR-based learning environments?

2 Methodological approach: conceptual framework construction

Although this paper advances a primarily conceptual and normative argument, its contribution rests on a systematic and transparent process of framework construction. Rather than proceeding through empirical testing or purely interpretive reflection, the analysis follows a structured methodology of conceptual selection, analytical alignment, and normative integration. Making this process explicit is essential for distinguishing theoretically grounded insights from ad hoc interpretation and for clarifying how the proposed design framework is generated.

The first step consists in the selective identification of core concepts that are both theoretically established and pedagogically relevant to XR-based learning environments. These include, in particular, distributed cognition, epistemic autonomy, collaborative learning, and embodied interaction. The selection is not exhaustive but guided by two criteria: (1) demonstrated significance within interdisciplinary research on learning and technology, and (2) relevance for addressing the limitations of immersion-centered accounts of XR. In this way, the conceptual basis of the framework is anchored in prior research rather than constructed in isolation.

The second step involves the analytical alignment of these concepts. Instead of treating them as discrete theoretical positions, the paper reconstructs their shared assumptions about the nature of cognition and learning—namely, that they are socially distributed, materially mediated, and relationally constituted. This alignment is achieved through comparative analysis, identifying points of convergence across philosophy of technology, educational theory, and XR research. The aim of this paper is to articulate a coherent analytical perspective that reveals their structural compatibility.

The third step consists in the normative integration of the aligned concepts into a design-oriented framework. Here, descriptive insights are transformed into normative criteria that specify the conditions under which XR environments can function as meaningful educational spaces. This includes the articulation of principles such as epistemic autonomy, inclusive participation, and socially structured interaction. The resulting framework is therefore not merely a synthesis of existing theories but a systematically constructed normative model that enables the derivation of concrete design implications.

Importantly, this methodological approach maintains a clear distinction between descriptive analysis and normative argumentation. While empirical and theoretical literature is used to ground the conceptual components, the framework itself operates at a normative level, specifying how XR environments ought to be designed in order to support meaningful learning. This distinction ensures analytical transparency and prevents the conflation of observed practices with justified design principles.

By explicating this process of framework construction, the paper demonstrates that its contributions are based on a structured conceptual methodology. This strengthens the validity of the proposed design principles and clarifies how the paper's overall argument is systematically derived from established research and theoretical reflection.

This positioning also reflects a practical orientation: the framework developed in this paper is intended to inform the design and evaluation of real-world XR learning environments. The paper provides normative criteria that can guide decision-making in educational institutions, platform development, and policy contexts. In this sense, the proposed account addresses a concrete problem of practice—namely how to design XR environments that do not merely optimize engagement or immersion, but actively support epistemic autonomy, inclusive participation, and socially grounded forms of learning in increasingly complex digital ecosystems.

Once the conceptual distinction between the metaverse and virtual reality has been clarified, it becomes necessary to explicitly characterize extended reality—and virtual reality in particular—as a medium and, more specifically, as a medium of communication. XR environments do not merely function as technological tools for visualization or simulation; they constitute communicative infrastructures that enable forms of interaction, co-presence, and meaning-making that exceed the affordances of earlier digital media [3]. In this respect, XR can be situated within established media-theoretical and educational frameworks that conceptualize learning spaces not as passive containers of information, but as dynamically structured environments shaped by interaction, relationality, and shared action. The unprecedented combination of immersion and interactivity in XR intensifies these dynamics by enabling embodied forms of communication, spatialized coordination, and real-time collaborative engagement.

From a media-theoretical perspective, XR can be understood as a communicative medium in its own right, comparable to earlier paradigm shifts introduced by writing, print, or digital networks. Like these media, XR does not merely transmit content but actively structures interaction, attention, and meaning-making. In educational contexts, this communicative function is particularly relevant, as learning emerges through coordinated action, shared reference, and dialogic exchange rather than through passive reception.

Educationally, this positions XR as a medium that transforms how learning activities are organized, how attention is guided, and how cognitive processes are distributed across users, artifacts, and environments. Framing XR explicitly as a communicative medium thus reinforces the paper's core claim that virtual learning spaces are not simulations of pre-existing classrooms, but distinct media environments whose altered spatial logic reconfigures the conditions of teaching, learning, and epistemic participation.

Public narratives about the metaverse—shaped prominently by Meta's promotional materials—tend to emphasize its immersive qualities. The claim that "the impact will be real" frames virtual environments as visually enhanced simulations capable of enriching instruction by rendering complex content more vivid. Such visions, exemplified by the presentation of magnified digital cells or immersive reconstructions of scientific objects, highlight immersion as the defining educational value of metaverse technologies. Yet this focus risks narrowing the pedagogical understanding of virtual environments to their sensory appeal alone.

XR environments must therefore be understood as socially and cognitively structured spaces instead of mere immersive simulations. This entails a conceptual shift that provides the analytical foundation for the normative design framework developed in the subsequent sections. This reframing beyond mere simulation also responds to a set of concrete societal and educational challenges that have become increasingly visible with the emergence of the metaverse: the growing influence of algorithmically curated learning environments, the formation of epistemic silos through personalization and filter bubbles, the commercialization of digital infrastructures, and persistent inequalities in access to immersive technologies.

Recent systematic research underscores that the educational value of XR cannot be reduced to immersive simulation alone. In a comprehensive review of XR-based learning environments, Emma [4] shows that positive learning effects depend less on technological immersion per se than on pedagogical design, cognitive alignment, and socially structured interaction. The review explicitly warns that uncalibrated immersion may increase cognitive load and obscure learning objectives, thereby reinforcing the need for conceptually grounded and human-centered frameworks so that the technology can become what Emma calls a kind of "extended education". This supports this paper's central claim that XR becomes educationally meaningful only where interaction, collaboration, and epistemic agency are structurally enabled. Therefore, the paper understands XR-based learning in terms of extended cognition and extended epistemic autonomy.

Research on virtual reality and collaborative learning supports the view that educational benefits of XR depend less on immersive simulation than on pedagogically structured interaction. Based on a review of 139 empirical studies, van der Meer et al. [5] show that collaborative learning effects in VR are primarily linked to social interaction, coordination, and shared knowledge construction, while immersive hardware alone is not decisive. At the same time, the review highlights a lack of established pedagogical frameworks for collaborative XR environments. This directly aligns with the paper's claim that XR becomes educationally meaningful only where interaction, collaboration, and epistemic agency are structurally supported.

Given that the central argumentative thrust of this paper explicitly moves *beyond simulation*, it is necessary to situate concepts such as simulation, presence, and immersion more explicitly within existing cognitive and interaction-oriented frameworks of XR research. A substantial body of literature has shown that immersion and presence are not merely technical features, but cognitively mediated phenomena emerging from the interplay between perceptual cues, bodily interaction, attention, and social context. In educational XR, these dimensions shape how learners orient themselves, allocate cognitive resources, and engage with others and with epistemic objects. At the same time, research on XR interaction models emphasizes that learning-relevant effects do not follow automatically from immersive simulation, but depend on how interactive affordances structure agency, coordination, and meaning-making [3, 6, 7].

From a cognitive perspective, presence and immersion modulate learning by shaping attention, embodiment, and the allocation of cognitive resources. Empirical research on XR interaction models shows that these effects are mediated by task structure, social coordination, and instructional scaffolding. Without such structuring, heightened immersion may even impede learning by increasing extraneous cognitive load or reducing opportunities for reflective distance [8–10].

Against this background, simulation, presence, and immersion should be understood as enabling conditions rather than as sufficient explanations of educational value. This perspective supports the core claim of the paper: that the pedagogical significance of XR environments lies not in immersive realism as such, but in the ways cognitive engagement, social interaction, and distributed action are orchestrated within these media environments.

A more substantive conception becomes clear when the metaverse is situated within the broader development of virtual reality. Michael Heim's classic triad—immersion, interactivity, and information intensity (11, 7)—already situates virtual reality not merely as an optical enhancement but as an epistemic medium that expands how bodies and minds engage with knowledge. Heim's earlier observation that VR "permits the active use of the body in the search for knowledge" (12, vii) points to a richer paradigm in which learning is enacted rather than simulated and delivered. Likewise, de Freitas and Veletsianos (13, 3) stress that virtual worlds open new learning spaces that exceed the logic of traditional instruction. Contemporary research in educational technology further underscores that the metaverse—understood in terms of the "Educational Metaverse" as a convergence of virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and other emerging technologies such as blockchain—plays an increasingly influential role in reconfiguring the conditions of modern learning [14], 1459).

At this point, it is important to clarify a conceptual distinction that is often blurred in both public and academic discourse. While virtual reality constitutes a technological modality within the broader spectrum of extended reality, the metaverse should not be understood as a fully realized virtual environment that already exists in a determinate form. Rather, the metaverse designates an emergent socio-technical horizon that integrates virtual environments, networked interaction, and institutional structures over time. In this sense, there is currently no fully developed metaverse; what exist instead are heterogeneous proto-metaverses that partially instantiate specific features—such as shared virtual spaces, avatar-mediated interaction, or persistent digital objects—without yet constituting a coherent, stable, or normatively integrated whole. Acknowledging this developmental status is crucial for avoiding conceptual inflation and for preventing an uncritical identification of the metaverse with virtual reality as such. Throughout this paper, the term *metaverse* is therefore used in a prospective and normative sense: not to describe an already existing technological reality, but to designate a direction of development towards an educational metaverse whose educational relevance depends on how these proto-metaverses are conceptually framed, pedagogically structured, and ethically governed.

Beyond its conceptual and normative analysis, this paper makes a distinct contribution to education research by reframing XR-based learning environments as socially and epistemically structured spaces rather than as immersive simulations. By shifting the focus from the technology of sensory immersion to social phenomena such as interaction, collaboration, and distributed cognition, the analysis advances current debates in educational technology that increasingly question immersion-centric models of XR learning. The paper provides a theoretically grounded framework for understanding how XR environments can support epistemic autonomy, inclusive participation, and collaborative knowledge construction—dimensions that are central to contemporary research on learning in virtual and hybrid spaces. In doing so, it complements empirical XR studies by offering normative design criteria and pedagogical principles that help educators and researchers evaluate not only *whether* XR technologies are effective, but *under which conditions* they promote meaningful, socially grounded learning processes.

Building on these foundations, this paper develops a normative understanding of the metaverse as a real educational space, one that is not reducible to fictional or commercial simulations. The didactic relevance of the metaverse does not lie primarily in immersive spectacle but in its capacity to integrate heterogeneous learning practices across physical and digital contexts. Hybrid forms of teaching—connecting analog and digital, individual and collective, local and global modes of engagement—can converge into coherent structures that support meaningful and not just simulated participation. In this sense, the metaverse functions as a cross-boundary environment, enabling learners to interact, collaborate, and contribute to shared cognitive processes regardless of physical location.

Historically, interpretations of the metaverse have been shaped by fictional imaginaries such as Stephenson's *Snow Crash* [15]. There, the metaverse appears as an "imaginary place," a computer-generated universe that is realistic but not real. While such depictions highlight the role of simulation, they also foreground a conceptual tension: can a simulated environment that is merely realistic but not real meaningfully support genuine educational (inter)action? If virtual space is conceived only as illusion, the pedagogical significance of the activities unfolding within it becomes difficult to justify.

To address this tension, this paper distinguishes between *illusion* and *virtual reality* understood in a realistic sense. Virtual actions, though not physically located, are real insofar as they occur within structured environments that support coordination, commitment, and shared meaning. Digital spaces can generate autonomous forms of coherence and continuity that render them socially and educationally significant. Virtual reality is therefore not merely a representation or simulation of the physical world but a domain in which new forms of interaction, participation, and agency can arise. In other words: Virtualizing learning means realizing it in non-actual ways through media and technology.

The present analysis can be situated within established learning theories that conceptualize learning as a fundamentally social, collaborative, and participatory process, such as Vygotsky (16). In particular, social learning theories emphasize that cognition is not confined to individual mental states but emerges through interaction, shared attention, and joint engagement with others and with material artifacts (Hutchins 17).

The metaverse, as conceptualized in this paper, provides a technologically mediated environment that structurally supports these learning dynamics. XR-based learning spaces enable forms of collaborative knowledge construction by allowing learners to jointly manipulate objects, coordinate perspectives, and externalize cognitive processes within shared virtual environments. Such settings align with core assumptions of collaborative learning approaches, according to which understanding develops through collective problem-solving, distributed cognition, and reciprocal engagement.

For education research, this reframing contributes a theoretically grounded account of XR learning that aligns immersive technologies with established models of social learning, collaborative knowledge construction, and distributed cognition. Instead of proposing a new learning theory, the paper clarifies how XR environments can instantiate and extend these approaches under conditions of virtual, hybrid, and networked interaction.

By framing XR environments as socially and epistemically structured spaces, this paper offers a conceptual bridge between philosophical accounts of cognition, autonomy, and engagement and educational theories that foreground social learning and collaborative knowledge construction. The contribution to education research thus lies not in proposing a new learning theory, but in clarifying how XR technologies can instantiate and extend well-established learning-theoretical principles under conditions of hybrid, virtual, and networked interaction.

Crucial to this understanding is the recognition that the metaverse operates as a technologically mediated social ecosystem. The selective focus on specific elements of the metaverse—such as avatars, spatial interaction, and collaborative affordances—follows from their functional relevance to the paper's central claim. In the context of the metaverse as a social ecosystem, these elements are not treated as isolated features but as structurally decisive components that shape epistemic agency, social coordination, and participatory learning. Rather than aiming at an exhaustive taxonomy of metaverse characteristics, the analysis prioritizes those dimensions that directly influence how learners engage with one another and with shared epistemic objects. The selection of these elements follows an explicit criterion: only those features are foregrounded that directly shape epistemic agency, social coordination, and participatory learning processes in XR environments; other dimensions (e.g., technical infrastructure or platform governance) are considered only insofar as they indirectly affect these core conditions.

Learners and instructors do not simply navigate visual scenes; they co-construct relational structures that determine whether an educational environment becomes inclusive, cohesive, or fragmented. Collaborative actions—coordinating tasks, negotiating interpretations, building shared objects of knowledge—are central to the stability and quality of virtual learning spaces. The social dimension is not an optional supplement to immersion but a foundational determinant of educational value.

A practical illustration of these dynamics can be found in XR-supported collaborative science instruction. Consider a virtual biology laboratory in which students investigate cellular processes by jointly manipulating interactive 3D models of organelles. Rather than observing a static simulation, learners coordinate tasks, negotiate interpretations, and collectively construct explanatory models. The virtual environment supports shared manipulation of objects, real-time annotation, and spatially distributed problem-solving. Such an example demonstrates that the pedagogical value of XR does not lie in sensory immersion alone but in the emergence of a socially distributed learning process—one in which knowledge becomes co-constructed through embodied interaction, mutual awareness, and joint epistemic agency.

This also implies that the metaverse must be designed to support inclusive and accessible participation. Users with different abilities, cultural backgrounds, and linguistic resources must be able to engage meaningfully within these environments. Virtual presence becomes pedagogically significant only when learners experience recognition, agency, and equitable opportunities to contribute. Ensuring this requires thoughtful design choices regarding interaction modalities, representational diversity, and the structuring of collaborative engagements.

To move from critique to constructive application, it is essential to translate these normative reflections into concrete design implications. While the critique highlights the risks of commercial bias and social fragmentation, the following recommendations prioritize: (1) technical interoperability to ensure learner mobility, (2) transparent algorithmic structures to protect epistemic agency, and (3) multi-modal interaction cues to promote inclusive social presence. These principles serve as a roadmap for developing XR spaces that are not merely immersive, but educationally transformative.

Recent evidence from higher education research further illustrates the limitations of simulation-centered approaches to XR learning. In their systematic review of 295 studies, Burke et al. [18] found that XR applications are still predominantly employed for simulation and visualization. At the same time, the review identifies challenges such as reduced peer interaction, cognitive overload, and inauthentic learning experiences. These findings support the present paper's central claim that the educational value of XR cannot be explained by immersion alone, but depends on socially structured interaction, collaborative knowledge construction, and the cultivation of epistemic autonomy. It is in this expanded, socially grounded sense that the metaverse reveals its potential as a transformative virtual educational space.

Revisiting the opening claim that "the metaverse may be virtual, but the impact will be real," it becomes clear that this formulation remains conceptually incomplete. As the preceding analysis has shown, the educational significance of XR does not derive from the translation of virtual experiences into real-world outcomes, but from the fact that virtual environments themselves can constitute meaningful hybrid spaces of interaction, cognition, and learning. The distinction between "virtual" and "real" thus gives way to a more integrated understanding of XR as a genuinely educational domain.

This reframing carries concrete implications for both theory and design. Theoretically, it requires moving beyond binary framings of virtuality and reality toward an account of XR as a relational medium in which meaning, agency, and learning are co-constructed. For design, it implies that the educational value of XR environments cannot be evaluated by the realism of their simulation, but only by the quality of the interaction, collaboration, and epistemic participation they structurally enable and afford.

Recent attempts to clarify the conceptual foundations of immersive media provide an important backdrop for understanding learning and social engagement in XR. As Perkis, Timmerer et al. (19) argue, immersive media experiences arise not simply from technological sophistication but from the dynamic interplay between sensory fidelity, interactivity, and the user's cognitive and emotional engagement. The White Paper emphasizes that immersion involves both system-level characteristics—such as multi-modal stimuli, spatial tracking, and interaction fidelity—and user-level responses that shape the sense of presence, agency, and co-presence within virtual environments. Crucially, Perkis, Timmerer et al. (19) highlight that immersive experiences are conditioned by human, technical, and contextual factors, including perceptual abilities, social configurations, and the situational demands of the environment. For educational settings, this means that XR learning cannot be understood merely as a form of simulation, but rather as a relational and situated experience in which meaning is co-constructed through interaction, collaboration, and the structuring of immersive media cues.

Having clarified the metaverse as a socially and bodily grounded and educationally meaningful XR environment, the next section examines how this conceptual shift informs a normative understanding of the metaverse as a didactic space.

3 The metaverse as a didactic space

This section develops a realist and normative account of the metaverse as a didactic space, focusing on the structural conditions that enable learning, participation, and agency in virtual environments. It examines accessibility, inclusivity, AI-driven personalization, and design principles as foundational elements of educational XR spaces.

Specifically, the challenge of algorithmic personalization and filter bubbles in XR must be linked to concrete learning outcomes. When AI-driven environments selectively present information based on past user behavior, they risk undermining epistemic autonomy and critical thinking—key goals of higher education. Such 'echo chambers' in the metaverse can restrict a learner's exposure to diverse perspectives, thereby hindering the development of collaborative knowledge construction and the ability to navigate complex, multi-perspective problems.

The term metaverse predates the recent surge of commercial interest surrounding it. Its appearance in the early 1990s, followed by a period of relative decline and subsequent resurgence since 2018, reflects broader technological developments as well as renewed cultural fascination with immersive virtual worlds. Although popular media narratives—such as Spielberg's *Ready Player One* (2018)—have shaped public imagination, scholarly debates increasingly situate the metaverse within the evolving architecture of Web 3.0, where decentralization, algorithmic intelligence, and new forms of digital autonomy converge.

Against this backdrop, it is important to avoid reducing the metaverse to a proprietary platform or to Meta's technologically driven vision. If the metaverse is merely an immersive façade, its pedagogical potential becomes difficult to articulate. The present account challenges this assumption by advancing a realist interpretation of virtuality. Virtual environments constitute genuine spaces of action, even if not physically instantiated. They allow forms of interaction—collaboration, inquiry, coordination, joint attention—that possess educational relevance in their own right. Digital technologies generate environments in which simulated, fictional, or symbolic elements can acquire autonomy and coherence, thereby supporting activities that meaningfully shape users' learning processes. Virtual space is thus not a diminished or derivative version of physical space, but a distinct domain in which new forms of epistemic engagement arise.

Understanding the metaverse as a didactic space therefore requires attention to the relational and structural conditions that enable these engagements. Unlike physical classrooms, where spatial constraints and temporal rhythms impose strict boundaries, virtual environments can expand or contract dynamically depending on the density and significance of the interactions occurring within them. Rather than serving as containers for information, they operate as relational architectures through which educational content, social presence, and collaborative processes become accessible.

A crucial aspect of such environments concerns inclusivity and accessibility. For virtual learning spaces to support equitable participation, they must accommodate diverse physical, cognitive, linguistic, and cultural needs. Adaptive interfaces, flexible navigation systems, and customizable representation options are not peripheral design features but fundamental conditions that shape learners' ability to enter, navigate, and meaningfully contribute to virtual settings. Inclusivity also extends to representation and the articulation of identity. Virtual spaces must allow learners to experience a sense of recognition, agency, and belonging. In educational contexts, this means that the design of environments—avatars, interaction modalities, and spatial metaphors—must support learners in expressing themselves and engaging with others without encountering barriers or distortions that undermine their presence. Virtual learning can only unfold its potential when participants are able to inhabit the space with a sense of legitimacy and confidence.

Moreover, conceptualizing the metaverse as a didactic space prompts reflection on the hybrid nature of contemporary educational practices. The boundaries between online and offline, analog and digital, synchronous and asynchronous learning have become increasingly permeable. The metaverse exemplifies this hybridity by enabling transitions across different modes of engagement: students may shift seamlessly between physical settings, virtual collaborative tasks, and AI-supported activities. This fluidity challenges traditional assumptions about the location and structure of educational interaction, calling for didactic approaches that recognize learning as distributed, networked, and co-constructed across diverse environments.

Seen in this light, the metaverse becomes a space where traditional educational dichotomies—real versus virtual, presence versus distance, individual versus collective—are reconfigured, as Floridi (32) also argued with regard to his conception of the Infosphere. The didactic question is no longer whether the metaverse can replicate physical classrooms, but how it can support new forms of learning activity, including collaborative inquiry, cross-border interaction (Akkerman and Bakker 21), and shared knowledge construction. These hybrid configurations open possibilities for learning that are not easily achievable in physical contexts alone.

In summary, understanding the metaverse as a didactic space requires a conceptual shift from viewing virtual environments as simulations toward recognizing them as structured, relational, and socially meaningful settings. Their educational value arises from their capacity to support inclusive participation, dynamic interaction, and hybrid forms of collaborative cognition—conditions that, when thoughtfully designed, enable learners to engage in authentic, meaningful, and transformative educational experiences.

To clarify the analytical structure of the argument, it is important to distinguish between two complementary but conceptually distinct steps: first, a critical diagnosis of current XR practices, and second, the derivation of normative design principles for educational XR environments. The critical analysis presented in this paper identifies recurring limitations of prevailing XR implementations, including an overemphasis on immersive spectacle, insufficient support for collaborative cognition, and a tendency toward algorithmically guided interaction that may undermine epistemic autonomy and inclusive participation. These shortcomings are not treated as contingent technical flaws, but as structural issues that arise when XR environments are designed primarily as simulations rather than as pedagogically structured spaces of action.

Against this critical background, the proposed design principles should be understood as normatively grounded responses to these identified limitations. Rather than offering prescriptive or technology-driven recommendations, the principles articulated in this paper follow analytically from the preceding critique: they specify the conditions under which XR environments can support socially grounded learning, collaborative knowledge construction, accessibility, and psychological safety. The normative force of these recommendations thus derives from the conceptual analysis of XR as a relational, epistemic, and educational space, ensuring that design principles are systematically justified within the overall argument.

To make the implications of this analysis more explicit, the core accessibility and inclusion principles proposed throughout the paper can be summarized as follows. First, XR learning environments should be designed around adaptive interaction modalities that accommodate diverse sensory, cognitive, and motor abilities, rather than presupposing a standardized user profile. Second, inclusive participation requires representational flexibility, particularly through customizable avatars and interaction settings that allow learners to express identity, agency, and presence without structural barriers. Third, accessibility must be understood as a social and relational condition: collaborative structures, clear interaction norms, and psychologically safe environments are essential for ensuring that learners can participate meaningfully and confidently. Finally, inclusive XR design should provide multiple pathways of engagement—synchronous and asynchronous, individual and collaborative—so that learners with differing needs, contexts, and spatial and temporal constraints can contribute to shared knowledge construction. Taken together, these principles translate the normative commitment to accessibility and inclusion into concrete design implications for XR-based educational environments.

The normative framework developed in this paper can be summarized along three interrelated dimensions. First, XR environments must support epistemic autonomy by enabling learners to critically engage with diverse information and perspectives, thereby avoiding the danger of virtual echo chambers, i.e. epistemic heteronomy. Second, they must facilitate socially structured interaction through mechanisms of collaboration, coordination, and shared knowledge construction. Third, they must ensure inclusive and accessible participation by accommodating diverse abilities, identities, and modes of engagement. These dimensions are analytically distinct but mutually reinforcing, forming the conceptual core of a didactically meaningful metaverse.

The concerns raised in this paper regarding AI-driven personalization, algorithmic curation, and filter bubbles are directly relevant to learning processes in XR environments. From a cognitive perspective, highly personalized content streams may reduce learners' exposure to epistemic novelty and conceptual challenge, thereby limiting opportunities for perspective-taking, conceptual change, and critical reflection. When learning environments systematically align content with prior preferences or behaviors, cognitive engagement risks becoming confirmatory rather than exploratory.

From an educational standpoint, this has significant implications for learner autonomy and critical thinking. Autonomy in learning presupposes not only access to information, but the capacity to encounter, evaluate, and integrate competing viewpoints. Algorithmically shaped XR environments may subtly shift learners from active epistemic agents to recipients of pre-filtered content, thereby undermining the conditions for independent judgment. In immersive and socially engaging XR contexts, these effects can be amplified, as the sense of presence and experiential coherence may mask underlying mechanisms of epistemic guidance.

For XR-based learning, these dynamics matter because immersive and interactive environments are particularly powerful in shaping attention, orientation, and meaning-making. If AI systems primarily optimize engagement or efficiency, rather than epistemic openness, XR learning spaces risk reinforcing cognitive closure rather than cultivate critical, reflective, and dialogic learning. The pedagogical challenge, therefore, is not to reject AI-driven personalization, but to design XR environments and affordances in which algorithmic support remains transparent, contestable, and aligned with the goal of epistemic autonomy and critical engagement.

Building on these considerations, several design principles are essential for ensuring equitable participation in XR-based learning environments. First, *adaptive interfaces* must accommodate diverse sensory, cognitive, and motor abilities by providing adjustable interaction modes, including voice commands, simplified gesture sets, haptic alternatives, and low-complexity navigation options (W3C 22). Second, *representational diversity* should be supported through customizable avatars that reflect a broad spectrum of identities, cultural backgrounds, and bodily configurations (Koch & Bockshecker 23). Third, *multi-modal feedback*—visual, auditory, and haptic—helps learners with differing perceptual strengths to remain oriented and engaged (Sigrist et al. 24). Fourth, *alternative pathways of interaction*, such as asynchronous collaboration tools or AI-assisted scaffolding, ensure that learners who face temporary or persistent constraints can contribute meaningfully (Holmes & Porayska-Pomsta 25). These principles transform accessibility from a peripheral technical feature into a foundational condition for inclusive, socially grounded XR learning.

These considerations regarding didactic structure, accessibility, and normative design provide the basis for a closer examination of how spatial and temporal conditions shape learning processes in virtual environments.

4 Rethinking space and temporality in virtual learning environments

The conceptual shift established in the preceding sections—from immersive simulation toward interaction, collaboration, and distributed cognition—has direct consequences for how the spatial and temporal conditions of virtual learning environments must be understood. If XR environments are not simulations of pre-existing spaces but relational architectures and affordances of meaning-making, then their distinctive spatial and temporal logic becomes a central pedagogical concern rather than a merely technical feature.

This section analyzes the distinctive spatial and temporal logic of virtual learning environments, conceptualizing them as epistemic spaces of action shaped by connectivity, relationality, and digital frictionlessness (Floridi 32). It explores how these properties affect learning, autonomy, and critical engagement in XR contexts.

The central claim of this section is that the distinctive spatial and temporal properties of virtual environments fundamentally reshape the conditions of learning by privileging relational connectivity over linear progression. This shift has direct implications for epistemic autonomy, as it expands the potential for knowledge integration while simultaneously increasing the risk of informational closure through algorithmic filtering.

Virtual knowledge and information spaces, such as those opened up in the metaverse, can be understood in terms of epistemic spaces of action. They do not exist statically, as physical teaching and learning spaces do, but are dependent on the epistemic interaction of their members. Due to their digital networking and integration structure, virtual actions have a different spatial and temporal logic than actions that take place in physical space [26]. The example of virtual objects shows that digital objects, such as learning content, are ubiquitously present. They can be accessed at any time and from any place, both individually and collectively.

The continuous accessibility and retrievability of instructional content in virtual environments give rise to a distinctive temporal structure—one that is better characterized by relationality than by linear succession. Within digital educational settings, it is no longer the temporal progression of material that assumes central significance, but rather the interconnection and contextual embedding of content elements. This shift underscores an intensified alignment with cognitive processing patterns. Such dynamics are especially pronounced in asynchronous learning contexts, where learners are afforded the flexibility to acquire, elaborate, and disseminate knowledge in ways that align with their personal rhythms and requirements. Here, the structure of the internet plays a pivotal role. It does not imply a sequential temporal logic but a presentist mode of connection.

Therefore, from an educational standpoint, the internet should not primarily be conceived as a mere medium of informational transmission, but rather as a virtual space of action in terms of connection, in which digital objects and processes are connected through a particular kind of relational frictionlessness. Floridi (32, 42) has called this structure "data superconductivity," a term that effectively describes the minimal resistance encountered in the flow and association of information within digital environments.

This virtual frictionless implies a fundamental qualitative shift from analog spatiality and entails significant pedagogical consequences. Whereas the relevance of linear temporality diminishes, the logical structure and didactic integration of learning content gains importance. This shift allows for a stronger focus on the conceptual coherence and cognitive significance of educational materials—more so than is normally possible in physical media or environments.

A theoretically sound definition of virtual teaching and learning spaces must take into account the specific ontological properties of digitally generated environments. Unlike traditional concepts of space, which are based on physical extension, virtual space is created through the relational architecture of digital objects and information units. It becomes visible as a dynamic and networked system of references in which the logic of connectivity replaces the logic of spatial proximity.

What distinguishes virtual space from its physical counterpart is its inherent flexibility: it can expand or contract depending on the semantic density and educational significance of the connections created within it. In this sense, virtual educational environments are not merely containers for teaching content, but are themselves shaped and structured by the cognitive and didactic logics that underlie their design. This perspective opens up new ways of understanding how meaning is created, navigated, and transformed in digital learning contexts.

From an educational perspective, virtual space expands to the extent that it promotes new connections and insights and enables the integration of previously unconnected knowledge. This process reveals a kind of digital horizon fusion, in which isolated intranets or knowledge domains merge into globally accessible, collectively designed knowledge environments.

However, virtual space also contracts when its relational architecture becomes closed off or self-referential, precluding external connections and thereby constraining the potential for transformative learning. A prominent example of such restriction is the phenomenon of the digital filter bubble. These algorithm-driven information environments, often shaped by artificial intelligence, present users primarily with content that aligns with their pre-existing knowledge or preferences. As a result, the epistemic and didactic breadth of virtual space is narrowed, reinforcing existing cognitive boundaries and inhibiting the development of a broader, critically engaged educational horizon:

> *"The basic code at the heart of the new Internet is pretty simple. The new generation of Internet filters looks at the things you seem to like—the actual things you've done, or the things people like you like—and tries to extrapolate. They are prediction engines, constantly creating and refining a theory of who you are and what you'll do and want next. Together, these engines create a unique universe of information for each of us—what I've come to call a filter bubble—which fundamentally alters the way we encounter ideas and information." [27], 9)*

Such digital environments systematically suppress new, dissonant, or challenging information—precisely the content that is essential for questioning entrenched beliefs and encouraging reflective self-criticism. In this respect, filter bubbles can be metaphorically described as "black holes" within the infosphere: they absorb and eliminate the diversity of perspectives necessary for critical thinking and epistemic autonomy, leading to a partial collapse of virtual spaces of knowledge and action by informational inflation or deflation.

This dynamic has significant implications for education and learning. By filtering out alternative viewpoints, filter bubbles erode the conditions for independent judgment and reflective engagement. They undermine the user's epistemic autonomy and contribute instead to a form of virtual epistemic heteronomy—where knowledge is no longer self-directed or critically evaluated, but increasingly shaped by algorithmic personalization and automated curation mechanisms:

> *"Because you haven't chosen the criteria by which sites filter information in and out, it's easy to imagine that the information that comes through a filter bubble is unbiased, objective, true. But it's not. In fact, from within the bubble, it's nearly impossible to see how biased it is." [27], 10)*

Building on the preceding considerations, normative criteria for the educational design of the metaverse can be articulated. Virtual teaching and learning environments should be structured in ways that support learners' informational autonomy—defined as the capacity to engage with information autonomously, to select, critically evaluate, and integrate it with other knowledge in a meaningful manner. This imperative becomes especially salient in light of the increasing integration of diverse digital media and technologies, above all artificial intelligence.

To safeguard epistemic autonomy, AI systems must be implemented as tools for enhancing and extending cognitive learning processes [28], not as substitutes for cognitive engagement, which would promote a state of digital immaturity [29]. Crucially, learning environments must facilitate a variety of interaction types, ranging from cooperative collaboration to critical and even confrontational discourse. Such dialogic spaces are essential for educational processes in which beliefs can be questioned and, if necessary, revised.

As artificial extensions of reality, the specific forms of interactivity in virtual spaces warrant further pedagogical interpretation. The subsequent sections will elaborate on the didactic implications emerging from the spatial logic of virtual environments.

The psychological implications of virtual didactic spaces deserve particular consideration. The fluid spatial and temporal structures of the metaverse can enhance engagement and motivation, yet they may also provoke feelings of disorientation or detachment if the relational architecture lacks clarity or stability. Emotional presence—defined as the felt sense of being affectively connected to others—is increasingly recognized as a prerequisite for meaningful learning in XR environments (Bertrand et al. 30). Designing virtual learning spaces therefore requires balancing cognitive frictionlessness with emotional grounding through stable social anchors, transparent interaction rules, and supportive avatar-mediated communication.

Building on this analysis of virtual space and temporality, the following section turns to the pedagogical implications of these dynamics for hybrid, networked, and AI-supported learning environments. These spatial and temporal dynamics are not self-regulating: they require deliberate pedagogical structuring to support epistemic autonomy rather than undermine it — a challenge that the following section addresses through a normative framework for hybrid and networked learning.

5 Toward a pedagogy of hybrid and networked virtual learning

This section articulates a pedagogical framework for hybrid and networked learning in the metaverse, focusing on epistemic autonomy, productive friction, ethical governance, and the integration of AI. It advances normative criteria for designing XR environments that support reflective, dialogic, and socially responsible learning.

If we understand the metaverse not only as an immersive-simulative entertainment medium, but in the sense of Web 3.0 as a network structure that increasingly integrates virtual objects and artificial intelligence, then we can include various phenomena of the contemporary Internet. The decisive question is whether digital structures on the Internet are (1) decentralized, (2) non-commercial and (3) autonomy-promoting.

The normative premise of a decentralized, non-commercial, and autonomy-promoting internet does not function in this paper as a descriptive claim about current technological realities, but as a critical benchmark for evaluating existing and emerging XR infrastructures. Given that most contemporary immersive platforms are proprietary, centralized, and commercially driven, the question is not whether such normative conditions are already fulfilled, but under which institutional, architectural, and governance-related constraints they could be approximated. In this respect, the metaverse should not be conceived as a direct technological extension of today's proprietary XR systems, but as a contested developmental trajectory in which alternative design models—such as decentralized network architectures, open standards, public-interest governance, and non-commercial educational infrastructures—remain conceptually and practically possible.

This claim should not be read as a prediction about imminent technological developments, but as a normative and critical hypothesis. Its function is to render existing XR infrastructures assessable by reference to educational and democratic values, rather than to suggest that current proprietary systems already meet these conditions.

Current research in distributed systems, Web3-inspired architectures, and public digital infrastructures indicates that immersive and interactive environments need not be structurally tied to platform capitalism (Srnicek 31). Within the framework of this paper, the educational metaverse is therefore understood as a normative horizon: a regulative idea that guides critical assessment of existing XR implementations and informs the design of future immersive learning environments, rather than as a technologically predetermined outcome of present proprietary systems.

Meta's latest technology obviously does not fully meet these conditions, as it is centralized and commercial. Hence, it is not compatible with the normative notion of the metaverse developed in this paper. However, even if the metaverse, understood as an immersive space, does not meet the aforementioned normative requirements, the aspects of fiction and simulation can be made fruitful for it. Fictionality allows us to adopt new perspectives and imagine alternative scenarios, for example in the form of gamification. Simulation allows for a normatively non-binding form of virtual action that can, under certain conditions, teleologically merge into virtual reality.

The internet is increasingly perceived not merely as a technological construct accessible to a limited group of experts, but as a pervasive element of everyday life. Luciano Floridi conceptualizes this condition as a hybrid mode of existence he terms "onlife" [32], 43), in which the boundary between online and offline realities dissolves. This shift is accompanied by novel, hybrid forms of media engagement that have far-reaching implications for teaching and learning.

From a didactic perspective, therefore, the internet should not be regarded solely as a conduit for information, but as a virtual action space that can be meaningfully harnessed for educational purposes. This perspective goes beyond Floridi's notion of the "infosphere," which primarily emphasizes the omnipresence and circulation of information. Instead, what comes into focus is an expanded conception of virtual reality as a pedagogically structured environment.

Within this framework, virtual teaching and learning spaces are not passive domains for the reception of content, but dynamic arenas for active, reflective, and socially situated knowledge construction. Their didactic value lies in enabling learners not only to access but also to interlink, contextualize, modify, and collaboratively engage with learning objects. This is especially relevant in light of the flexible and multimodal integration of digital media and technologies such as artificial intelligence.

From a pedagogical perspective, the spatio-temporal frictionlessness characteristic of digital media is not merely a quantitative benefit, but a qualitatively distinct structural property that aligns with the logic of networked cognition. The interactive and fluid nature of virtual hypertext environments enables concepts to be defined not in isolation, but in relation to one another, thus allowing for the exploration of learning objects within comprehensive, contextual frameworks. The didactic meaning of such objects becomes clear only through their placement in an evolving semantic web—a web that can be continually expanded and restructured through the collaborative engagement of multiple participants.

While this form of intersubjective exchange is theoretically possible within traditional, text-based media—such as letters, printed texts, or card catalogues—these media are constrained by spatio-temporal limitations and involve a degree of communicative friction. In contrast, the near-frictionless character of digital learning environments emerges as a constitutive feature rather than a contingent one. It plays a pivotal role in facilitating novel didactic configurations, particularly those afforded by immersive and interactive platforms such as the metaverse.

However, frictionlessness also poses risks: when content flows too easily without critical resistance, learners may lose the opportunity to engage in sustained reflection or to challenge dominant narratives, which leads to an inflation and instability of the virtual learning space. Filter bubbles and algorithmically curated content ecosystems may reinforce cognitive closure rather than openness, leading to a deflationary space. Didactic design must therefore introduce *productive friction* into virtual environments—moments of dissonance, critical questioning, and dialogic confrontation. Learning is not only about connection but also about disruption, re-evaluation, and transformation. Educators should not merely rely on the efficiency of AI-enhanced platforms, but ask how these tools can support epistemic autonomy. AI should act as a cognitive amplifier—not as a substitute for thinking that leads to cognitive off-loading [33].

As XR environments become more interconnected with AI systems, issues of user safety and ethical governance acquire heightened significance. Algorithmic curation, behavioral data extraction, and AI-driven personalization may reinforce biases or create asymmetric dependencies. A pedagogically responsible metaverse must therefore establish transparent data practices, safeguard users from unwanted behavioral nudging, and ensure that automated agents support rather than undermine epistemic autonomy. Ethical design further implies establishing clear behavioural standards within XR spaces, addressing harassment, exclusion, and misuse of avatars—phenomena that directly affect learners' psychological well-being and sense of security.

In digital virtual environments, the notion of physical space undergoes a transformation, emerging instead as a complex system of orientation and relationality. The spatial concept can be further elaborated through the lens of expansion—understood not as a fixed physical measure, but as a dynamic process realized through the creation, maintenance, and modulation of connections. Space, in this sense, is always extended, yet the nature of this extension is fluid and variable.

Unlike physical space, virtual space—especially in its epistemic form—can be deliberately expanded through the establishment of meaningful links, or conversely, contracted through the dissolution or severing of such connections. This dynamic capacity renders the internet not merely a medium for the transmission of information, but a performative space in its own right—one in which knowledge is enacted, reshaped, and restructured through ongoing acts of digital interaction and cognitive engagement.

The altered spatial logic of the internet, in contrast to that of analogue media, promotes a growing density of learning objects that generate emergent knowledge contexts through their interconnectivity. With each additional link—such as those enabled by artificial intelligence—these contexts increase in complexity. However, this development should not primarily be understood in quantitative terms, such as an increase in frictionlessness, data volume or file size. Rather, the focus is on qualitative changes resulting from the seamless integration and structural consolidation of digital information.

Within virtual spaces, learning becomes real not as the passive accumulation or reception of information, but as an ongoing process of meaning-making through epistemic acts of connection, transformation, and collaborative engagement. These practices constitute a distinctly virtual mode of education, characterized by the progressive consolidation of a dynamic and evolving knowledge network. In the digital learning environments of the metaverse, knowledge fundamentally differs from raw information in that it is performatively appropriated rather than passively received. Knowledge presupposes a web of interrelations, the holistic structure of which must not only be understood but actively co-constructed by learners. The formation of such epistemic networks within virtual space does not follow fixed, linear trajectories, but instead invites—and indeed requires—flexible, non-linear movements of thought and exploration.

In addition to technical accessibility, XR learning spaces must cultivate psychological safety and clear behavioural norms. Social VR research shows that harassment, exclusion, or manipulative avatar behaviour can undermine learners' sense of security and belonging [34]. Recent work on VR ethics emphasizes that psychological safety is a core precondition for meaningful participation in immersive environments. Raja and Al-Baghli [35] show that harassment, manipulative behaviour, and other forms of immersive misconduct are repeatedly identified by researchers, policymakers, and users as ethical risks that undermine trust, wellbeing, and equitable participation in virtual spaces. Their study highlights that VR harassment can have intensified emotional consequences due to the heightened sense of presence, and that users frequently report intimidation, boundary violations, or exposure to inappropriate content as threats to their sense of security and belonging. Such findings underscore the need for XR learning environments to implement explicit safeguards—consent mechanisms, moderation tools, and clear behavioural norms—to ensure that collaborative learning can unfold within psychologically safe conditions.

Therefore, ethical design requires transparent moderation tools, consent-based proximity controls, and clear interaction boundaries that prevent misuse of embodied features such as gaze, gesture, or spatial positioning. XR-specific safety mechanisms are not merely protective measures; they are pedagogical prerequisites that enable learners to participate with confidence, express vulnerability, and engage in meaningful dialogue.

If the metaverse is conceptualized as a virtual space for teaching and learning, its distinctive spatial logic—combined with the capacity to integrate technologies such as artificial intelligence—enables the externalization of mental content, particularly thoughts, in a way that is no longer exclusively bound to the individual subject who originally produced them. What results is an epistemic space that is accessible and modifiable by all participants in the educational process, in contrast to the inherently static and closed nature of printed media.

In this framework, the teaching and learning context takes shape as a dynamic, networked structure that remains open to continuous transformation. This openness applies irrespective of the original sources of content, thus fostering a learning environment characterized by ongoing development, shared authorship, and dialogic co-construction. The metaverse, in this sense, constitutes not merely a platform for knowledge dissemination but a participatory epistemic infrastructure.

In the metaverse, the traditional roles of teachers and learners are becoming increasingly blurred. Networking makes these roles more flexible, though they are not entirely dissolved. Consequently, virtual learning environments are characterized by horizontal interaction rather than hierarchical, front-facing instruction. While similar forms of collaborative learning exist in physical settings, such as study groups or plenary discussions, they lack the interconnected, hypertextual adaptability that the internet embodies.

To further clarify how collaboration unfolds in XR environments, it is useful to identify specific mechanisms that enable shared epistemic activity (Perkis, Timmerer et al. 19). First, *joint attention* is established through spatialized cues—such as gaze direction, gesture tracking, or object highlighting—which allow learners to orient toward common focal points. Second, *mutual monitoring* is facilitated by avatars' embodied actions, enabling participants to coordinate their contributions in real time. Third, *shared manipulation* of virtual objects supports collective problem-solving, as multiple users can simultaneously reshape, annotate, or reorganize learning materials. Fourth, *distributed role-taking* follows: learners alternate between guiding, observing, constructing, and evaluating depending on their expertise and engagement. These mechanisms make XR a uniquely powerful medium for collaborative knowledge construction, far exceeding the possibilities of traditional screen-based platforms.

From a didactic standpoint, the metaverse serves as a collective reference framework in which individual teaching and learning activities are externalized beyond the boundaries of the subject and remain continuously accessible. This reduces the need for physical presence among participants and focuses attention more strongly on the content itself. Learners' involvement, understood as the hypertextual interconnection of content, is a fundamental element of the learning process within virtual environments, not merely a technical or procedural aspect. The resulting adaptability enables seamless integration with other educational contexts, as well as with media and technologies such as artificial intelligence. This constitutes a qualitative advantage that cannot be replicated in traditional, location-bound educational formats.

Against this pedagogical backdrop, the next section focuses on a key mediating element of XR learning environments: the avatar as a didactic interface of embodiment, interaction, and collaboration.

6 Avataric didactics

This section examines the avatar as a central didactic medium in XR-based learning, emphasizing its role in embodiment, interaction, representation, and collaborative knowledge construction. It analyzes how avatar design influences inclusion, agency, and social presence in virtual learning environments.

From a didactic perspective, the avatar plays a key role as a virtual embodiment of teaching and learning individuals. Its significance lies less in its immersive properties than in its function as an integrative medium that typically connects separate areas. However, the avatar is not to be understood as a passive medium that transfers information but as an active medium of interaction and connection. In the metaverse, avatars are not separated from the physical world but are controlled by real, physically present users. This interaction underscores the avatar's function as a link between digital and virtual environments on the one hand and analog and physical realities on the other. This makes the avatar a didactic medium that facilitates interaction between virtual and physical educational contexts. Existing as an avatar in the metaverse allows us to epistemically interact not only in terms of language but also in terms of movement. As such, an avatar can be understood as an epistemic virtual use of our body.

In collaborative educational scenarios, avatars function as mediators of group interaction and joint problem-solving. XR platforms allow learners to co-create objects, explore shared environments, and engage in distributed tasks in ways that foster cooperative reasoning and collective intelligence. These forms of avatar-based collaboration reveal how virtual embodiment can enhance coordination, mutual awareness, and shared intentionality. At the same time, careful design is required to prevent dominance effects, stereotyping, or exclusion within avatar-mediated group dynamics. Ensuring equal participation thus becomes a central challenge for socially oriented XR didactics.

From a didactic perspective, avatars offer users the opportunity to reflect on and actively shape their own roles, which can be freely chosen and flexibly adjusted within virtual environments. This is made possible by the non-physical nature of avatar interactions, which are inherently low-barrier and, in principle, accessible to all. As a result, the didactic principle of "entry neutrality" can be realized, which supports inclusive and intersectional thinking and practice [36], 9).

The seamless interaction between avatars fosters deeper identification with the actual subjects of teaching and learning—not just through immersion in the virtual world, but through structured integration and interconnectedness. Also, avatarization enables a form of virtual closeness between educators and learners, transcending spatial and temporal boundaries on a global scale. Furthermore, the use of avatars introduces a subtle gamification of educational participation—not as mere playfulness, but as an engagement with structured rules, which can hold significant didactic value. Finally, AI avatars can be designed to interact with users individually. These kinds of avatars need not necessarily have virtual bodies but can be realized as chatbots [37], which serve the purpose to extend the educational informational space.

These reflections on avatar-mediated interaction lead to the concluding section, which synthesizes the paper's main contributions and outlines implications for future research and educational practice.

7 Conclusion

This concluding section synthesizes the paper's conceptual and normative contributions, restating its central claims about the educational significance of the metaverse and outlining future directions for research and XR-based pedagogical design.

The metaverse, when understood as a hybrid and relational learning environment, reveals educational potentials that extend far beyond immersive visualization. Its didactic significance lies in its ability to function as a dynamic epistemic space in which learners engage in meaningful interaction, collaboratively construct knowledge, and navigate forms of embodiment that integrate physical, cognitive, and digital dimensions. Rather than replicating physical classrooms, virtual learning environments offer a distinct architecture that reshapes how learners connect with content, with one another, and with the structures that guide their educational experience.

Central to this potential is the notion of epistemic autonomy. The metaverse enables learners to access, evaluate, and integrate information within expansive networks of meaning; yet this autonomy remains fragile in the face of commercialization, algorithmic bias, and the risk of informational narrowing. The same frictionless connectivity that promotes exploratory learning can also undermine critical engagement when content is curated according to opaque personalization mechanisms or when virtual spaces lack the structural supports needed for reflection and resistance. Ensuring that learners remain active agents rather than passive recipients therefore requires the deliberate design of environments that foster dialogue, diversity of perspectives, and constructive friction.

Equally important are the social and ethical dimensions of metaverse-based education. Learners encounter one another in forms of virtual presence mediated by avatars, interfaces, and spatial metaphors. These elements shape not only the flow of interaction but also experiences of recognition, inclusion, and belonging. Collaborative learning in virtual environments depends on structures that support equitable participation, prevent exclusionary dynamics, and promote psychological safety. When such structures are absent, virtual spaces can amplify existing inequalities or reproduce biases embedded in interaction design.

Thus, accessibility, representation, and user protection cannot be treated as supplementary considerations—they are foundational to the pedagogical legitimacy of virtual learning environments. The emotional and relational dynamics of virtual learning are equally decisive. Engagement, motivation, and sustained attention rely on learners' sense of social presence and affective connection within the environment. Avatars and interaction modalities play a crucial role in cultivating these connections; they enable learners to inhabit virtual spaces with expressive nuance, to experience proximity and reciprocity, and to participate in shared tasks that build cohesion. When these dynamics are supported, virtual learning environments can generate communities of practice that transcend physical boundaries and foster deep, collaborative meaning-making.

At the same time, the integration of artificial intelligence within virtual spaces introduces transformative opportunities and new responsibilities. AI systems can enhance learning by supporting exploration, personalization, and cognitive extension, but they can also entrench dependence or distort epistemic agency. Their pedagogical value depends on careful calibration—ensuring that they amplify rather than diminish the learner's role as a reflective and autonomous participant in the learning process.

In sum, the metaverse offers a powerful framework for reimagining education in a digitally interconnected and decentralised world. Its capacity to integrate hybrid forms of interaction, support collaborative inquiry, and expand the possibilities for embodied and distributed cognition positions it as a promising environment for future learning. Yet this potential can only be realized when educators, designers, and institutions intentionally craft virtual spaces that balance openness with structure, flexibility with ethical safeguards, and immersion with epistemically meaningful relationality.

A reflective, learner-centered approach to virtual pedagogy must therefore guide the development of the metaverse as an educational space—one that not only broadens access and fosters innovation but also cultivates autonomy, inclusivity, depth of engagement, and shared responsibility. When these conditions are met, the metaverse becomes not merely a technological novelty, but a coherent, socially grounded environment capable of supporting transformative educational experiences.

In this respect, the proposed framework offers a structured point of orientation by integrating three core dimensions—epistemic autonomy, social interaction, and inclusive design—through which the educational potential of XR environments can be systematically evaluated. It advances a normative framework that clarifies how interaction, collaboration, epistemic autonomy, accessibility, and psychological safety jointly constitute the pedagogical value of the metaverse. By systematically linking philosophical accounts of virtuality with learning-theoretical and didactic concerns, the analysis provides criteria for evaluating when and how XR environments support meaningful learning.

Future research should build on this framework by empirically investigating how these normative design principles can be operationalized across different educational contexts and learner populations. In particular, further work is needed on the role of AI-supported personalization, avatar-mediated interaction, and accessibility mechanisms in shaping learner autonomy, critical engagement, and collaborative knowledge construction in XR-based learning environments.

While the metaverse offers promising conditions for hybrid, collaborative, and socially grounded forms of learning, several questions remain open for further investigation. First, more empirical research is needed to examine how different groups of learners—including those with diverse physical, cognitive, and cultural backgrounds—experience accessibility, representation, and agency within avatar-mediated environments. Second, the psychological dynamics of virtual presence, emotional engagement, and interpersonal trust warrant closer study, especially as they shape learners' motivation, well-being, and relational safety. Third, the integration of artificial intelligence and technologies such as blockchain into XR learning spaces raises unresolved issues concerning autonomy, authorship, bias, and the distribution of pedagogical authority. Finally, future research should explore how didactic design principles can be operationalized into concrete frameworks for building inclusive, ethically aligned, and cognitively robust virtual learning ecologies and affordances. Advancing these lines of inquiry will be essential for realizing the full educational potential of metaverse-based environments.

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References

1. Hollan J, Hutchins E, Kirsh D. Distributed cognition: toward a new foundation for human-computer interaction research. ACM Trans Comp-Hum Inter (TOCHI). 2000;7(2):174–96. https://doi.org/10.1145/353485.353487
2. Clark A. Being there: putting brain, body, and world together again. Cambridge: MIT Press; 1996.

3. Dalgarno B, Lee MJW. What are the learning affordances of 3-D virtual environments? Br J Edu Technol. 2010;41(1):10–32. https://doi.org/10.1111/j.1467-8535.2009.01038.x
4. Emma O. Extended reality in the digital age: a literature review on technology-driven learning environments. Comp Educ X Real. 2026;8:100127. https://doi.org/10.1016/j.cexr.2025.100127
5. van der Meer N, van der Werf V, Brinkman W-P, Specht M. Virtual reality and collaborative learning: a systematic literature review. Front Virtual Real. 2023;4:1159905. https://doi.org/10.3389/frvir.2023.1159905
6. Gibson JJ. The ecological approach to visual perception. Boston: Houghton Mifflin; 1979.
7. Norman DA. The psychology of everyday things. New York: Basic Books; 1988.
8. Mayer RE. Multimedia learning. 3rd ed. Cambridge: Cambridge University Press; 2021. https://doi.org/10.1017/9781108894333
9. Parong J, Mayer RE. Learning science in immersive virtual reality. J Educ Psychol. 2018;110(6):785–797. https://doi.org/10.1037/edu0000241
10. Sweller J. Cognitive load during problem solving: Effects on learning. Cogn Sci. 1988;12(2):257–85.
11. Heim M. Virtual realism. New York/Oxford: Oxford University Press; 1998.
12. Heim M. The Metaphysics of virtual reality. Oxford/New York: Oxford University Press; 1993.
13. de Freitas S, Veletsianos G. Editorial: crossing boundaries: learning and teaching in virtual worlds. Br J Edu Technol. 2010. https://doi.org/10.1111/j.1467-8535.2009.01045.x
14. Peng S, et al. A Survey for Educational Metaverse: Advances and Beyond. Procedia Computer Science. 2024;246:1456–65. https://doi.org/10.1016/j.procs.2024.09.590
15. Stephenson N. Snow crash. New York: Bantam Books; 1992.
16. Vygotsky LS. Mind in society: the development of higher psychological processes. Cambridge, MA/London: Harvard University Press; 1978.
17. Hutchins E. Cognition in the wild. Cambridge, MA/London: MIT Press; 1995.
18. Burke D, Crompton H, Nickel C. The use of extended reality (XR) in higher education: a systematic review. TechTrends. 2025;69:998–1011. https://doi.org/10.1007/s11528-025-01092-y
19. Perkis, A Timmerer, C et al. QUALINET White Paper on Definitions of Immersive Media Experience (IMEX); 2020. https://arxiv.org/abs/2007.07032
21. Akkerman S, Baker A. Boundary Crossing and Boundary Objects. Review of Educational Research 81(2); 2011. https://www.doi.org/10.3102/0034654311404435
22. W3C (World Wide Web Consortium). XR Accessibility User Requirements. W3C Working Group Note 25; August 2021. https://www.w3.org/TR/2021/NOTE-xaur-20210825
23. Koch B, Bockshecker A. Designing Avatars for All: Requirements for Diversity, Interculturality, and Inclusion in Virtual Worlds. ICIS 2025 Proceedings, 2025.
24. Sigrist, R et al. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review. Psychon Bull Rev 20; 2013.
25. Holmes W, Porayska-Pomsta K. (eds.). The ethics of artificial intelligence in education: Practices, challenges, and debates. New York, NY: Routledge, 2023.
26. Noller J. Digitalität: Zur Philosophie der digitalen Lebenswelt. Basel: Schwabe; 2022.
27. Pariser E. The filter bubble: how the new personalized web is changing what we read and how we think. New York: The Penguin Press; 2011.
28. Noller J. Extended human agency: towards a teleological account of AI. Human Soc Sci Commun. 2024. https://doi.org/10.1057/s41599-024-03849-x
29. Noller J. A kantian critique of artificial intelligence. Dan Yearb Philos. 2026. https://doi.org/10.1163/24689300-bja10090
30. Bertrand P et al. Learning empathy Through virtual Reality: Multiple Strategies for Training empathy-Related Abilities Using Body Ownership illusions in embodied virtual Reality. Front. Robot. AI, 22; 2018. https://doi.org/10.3389/frobt.2018.00026
31. Srnicek N. Platform Capitalism. Cambridge: Polity; 2017.
32. Floridi L. The 4th Revolution. How the Infosphere is Reshaping Human Reality. Oxford: Oxford University Press; 2014.
33. Gerlich M. AI tools in society: impacts on cognitive offloading and the future of critical thinking. Societies. 2025;15:6. https://doi.org/10.3390/soc15010006.
34. Blackwell L, Ellison N, Elliott-Deflo J, Schwartz R. Harassment in social virtual reality: challenges for platform governance. In: Proceedings of ACM CSCW; 2019. https://doi.org/10.1145/3359202
35. Raja US, Al-Baghli R. Ethical concerns in contemporary virtual reality and frameworks for pursuing responsible use. Front Virtual Real. 2025;6:1451273. . https://doi.org/10.3389/frvir.2025.1451273
36. Bitkom. Metaverse & Lernen . Berlin: Bitkom; 2023. https://www.bitkom.org/sites/main/files/2023-03/BitkomLeitfadenMetaverseundLernen.pdf
37. Fink MC, et al. AI-based avatars are changing the way we learn and teach: benefits and challenges. Front Educ. 2024;9:1416307. https://doi.org/10.3389/feduc.2024.1416307.

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