

Embodied learning in the era of Artificial Intelligence and immersive technologies: corporeality, digital mediation, and cognitive artifacts for an innovative teaching process.

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Abstract: The current projection of technological infrastructures leads us to analyze how the emergence of embodied education as a pedagogical paradigm is redefining the interactions and inferential methods through which students relate to knowledge, in the construction of artifacts, and in learning environments themselves. Processing knowledge by shifting it from a neutral to an "embodied" position allows us to think of our body not as a simple sensory vehicle, but as an epistemic mediator that structures attention, perception, and the construction of meaning (Habrahanson et al. 2023). From this scenario, the growing diffusion of immersive technologies such as virtual reality, augmented reality, phygital environments, and AI-based systems give rise to new opportunities for experiential educational design in which corporeality becomes a lever for engagement, conceptual understanding, and the personalization of educational paths (Farina, 2021). From this perspective, digital artifacts take on significant significance precisely because of their role. Indeed, when designed according to principles of digital mediation, they facilitate the transition from concrete experience to abstract representation, supporting deep and situated learning processes. Consider how essential it is to preserve the corporeal dimension of learning, seeking to avoid deviations from corporeality by promoting a balanced approach between automation, human agency, and teacher mediation. This paper aims to analyze the relationship between corporeality, emerging technologies, and digital artifacts, outlining implications for instructional design, teacher training, and the development of dynamic, inclusive, and cognitively satisfying learning environments. (Ciccarelli, Tafuri, 2024).



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Introduction

The growing development of Artificial Intelligence and immersive technologies is requiring a critical review of traditional learning models and all forms of

educational mediation. Within this context, the transformations that have occurred over time have been reflected in research rooted in the theory of Embodied Cognition, offering insights that have led to the identification of the paradigmatic process of embodied learning. This cognitive shift has led to the emergence of a particularly fruitful perspective for understanding the relationships that generate knowledge developed through the dynamic interaction between the body, environments, and cognitive artifacts.

At the same time, the integration of AI devices into educational settings, if carefully constructed, enables personalization, adaptive feedback, and metacognitive support that revolutionize learning environments into intelligent and effective ecosystems capable of dynamically responding to the inherent needs of human beings. Indeed, if used consciously, AI can become a co-agent of phenomenological disembodiment but also develop as a cognitive mediator capable of enhancing and amplifying the bodily experience, including through the judicious use of the Embodied Conversational Agent (Nosov, Shtekhin, Lyubchenko, 2024).

Immersive technologies contribute to the creation of learning environments characterized by innovative and dynamic practices, stemming from a close relationship between automated AI-based structures and Embodied Education approaches, which insist on the necessary interrelation with corporeal irrationality, dramatization processes, and the development of physical models that meaningfully approximate the real world. These practices, embedded within a network of conscious relationships that serve existential needs, highlight the potential of AI as a tool for observation, planning, and reflection, while also highlighting the critical issues of algorithmic bias, the development of teachers' digital skills, and the need to maintain a positive alignment between pedagogical objectives and technological choices.

1. Technological Immersion and Extended Corporeality. Toward a Revolutionary Theoretical Framework

Today, digital environments are decisively underscoring the fundamental role that the educational context and pedagogy as a whole must address and organize. The intensity with which immersive technologies, including virtual reality, augmented reality, mixed reality, and XR ecosystems (Di Natale et al., 2024), are expanding and becoming embedded in society are radically redefining the relationship between the body, perception, and knowledge. Their spread in recent years has brought about an epistemic shift that focuses not only on the analysis of experiential technological

mediation, but also on a new form of bodily expression understood as a cognitive, sensorial, and relational interface.

Many recent studies (Gallagher, 2020; Baxter & Hainey, 2024) converge in affirming that immersive technologies are not exclusively tools for representing knowledge, but ontogenetic environments, capable of generating forms of social belonging, agency, and identity that transcend the traditional distinction between physical corporeality and its digital idealization and embodiment. If we look at the very concept of corporeality in hypermedia environments, what is essential to revisit is the idea that technological corporeality cannot be considered an artificial extension of the human body without fully understanding the similarity of an emergent process, which sees the technological distribution of experience processed through sensors, avatars, simulated environments, and information flows as the origin of autonomic inferences.

Considering corporeality as an expressive extension structured as a cognitive interface, theories of Embodied Cognition (Varela, Thompson, & Rosch, 2017) demonstrate how knowledge cannot be considered purely a mental process, but rather a situated and prolonged activity, embodied in its most complex manifestations and inferentially originating precisely from the relational nature of knowledge. The transformations that unfold with the use of immersive technologies lead to the identification of our body as a node of multidimensional interaction.

If we consider how virtual reality has evolved today, and the epistemological nuances drawn from scientific and humanistic perspectives, the idea of the body cannot be considered exclusively as a represented object; it must be analyzed under a new form of remapping, tracing, and modulated extension, as a cognitive reflex. Like a well-oiled machine, humans experience and verify a sense of belonging and presence that arises from the integration of multiple elements, which make the whole cohesive and cohesive.

All these aspects, constructed and managed as a single apparatus, are oriented along an experiential path supported by visual input, haptic feedback, motion tracking, and multisensory synchronization. These elements lead to the consideration that representing the body in its most extreme forms, understood as a blend of physical and mental characteristics, cannot help but refer to the body schema derived from sensory input and a semantic description originating from the representation and verbal engagement of the body parts.

The influence of visual input is essential for understanding bodily belonging and determining bodily sensations. In current literature, instrumental verification of synchronization stimulated by external inputs has shown how it can alter the

perception of the body, its nuances in reality, and what society itself identifies as physiologically produced.

As a prominent feature, and linked to the surrounding environment, haptic feedback plays a fundamental role in the very configuration and awareness of corporeality in specific contexts, namely digital ones, precisely because of its ephemeral and suggestive nature.

Precisely because of their natural exposure to continuous revolutions, both formal and informal, haptic feedback presents itself as transformative and remediated structures in the human-machine relationship. Like a series of physical signals that an external system sends to the human body to communicate information about the ongoing interaction, these structures aim to simulate and configure prototypical sensations of interaction with real objects. Indeed, unlike normal audio or visual feedback, these feedbacks stimulate and engage tactile mechanisms, such as the muscles and tissues that surround the human body, eliciting sensations that humans can specifically recognize as vibration, external pressure, internal and external force, and contact surfaces.

Understanding haptic feedback requires observing and analyzing the mechanisms that integrate hardware, software, and sensory perception.

The latency between the haptic response and human action becomes crucial, precisely because high latency times make the frame and interface unresponsive and frustrating, undermining the immersion process. If we consider that a potential coherence between sight, sound, and touch improves the simulation's credibility, we recognize that effectiveness increases when the sensory experience is closely synchronized and contextualized with human action.

Precisely for this reason, the fields of application of haptic feedback span different systemic levels and socio-contextual structures, from virtual and augmented reality, where touching objects, feeling their mass, or perceiving the texture of surfaces becomes natural, and thus a new form of extension of corporeality, precisely when audio and visual inputs are combined with haptic feedback.

The fields of sensory perception, referring to the vision of the body, dynamically linked to environmental, stereotyped, and identity-related inferences of a territory rich in interconnected knowledge, create fertile ground for the emergence of known and shared phenomena.

Sensory synchronization is essential for building body representation, as it allows the brain to coordinate and integrate information from different sensory modalities. This process is essential for perceiving the position of the limbs in space, planning movements, and resulting awareness of one's body within structured environments. Body representation shapes the multidimensional model that includes

the body schema, the structural description of the body, and the semantics of the body itself.

The integration of all these elements creates what Slater (2009) defines as the place illusion and plausibility environment, which describes how humans react by responding realistically to situations and events that occur within an immersive virtual reality system. He highlighted how reiteration and contact with virtual environments lead to a requalification of human sensations, demonstrating how these environments, if configured according to realistic canons and through a continuous relationship with virtually created events, can direct awareness of one's own body towards an extension of the very concept of corporeality.

On this basis, hypermedia systems, supported by mechanical and automated devices, emerge as hybrid systems, precisely because of the nuanced and personalized nature of emotional inferences. In contexts where the ability to adapt information to the knowledge of participants in social interactions can paradoxically lead to cognitive delegation and thus mental retroversion. This process leads to an inadequate structural conception of the body, still deeply rooted in the biological etiology of the term, where the nuances exhibited by the body lead to a natural cerebral elongation.

What is considered, therefore, a plausible illusion alters the state of the art that nourishes our awareness, whether mental or corporeal, bringing it to a limit from which we do not wish to deviate. Although we are grappling with relational nuances that require a rethinking of the embodied role of corporeality in society, the digital revolution has highlighted entirely new and still little-explored aspects and perspectives.

Our unrealistic idea of the body's positioning between physical functions and mental actions must be strengthened by training data to convert meanings, transforming irrational ideological sources into potentially real reflections. This very thought has led to studies that have focused on defining digital corporeality and its environmental implications. Digital corporeality, in this context, represents a rethinking of the human body as a hybrid entity, in which experience, from an external element currently considered embodied, intertwines with virtual and digital technologies, creating the backbone that allows us to interact by perceiving the sensations of the surrounding world.

The relentless progression of cognitive artifacts and digital transformation has gradually rendered and profoundly eviscerated the body's role as a mediator of reality. Thus, it becomes not only an inevitable element in the human-world relationship, but a technological disembodiment, reacting to the world in a hybrid, undefined guise, somewhere between biological and hypermedia transformations. If we

consider the body, as described in literature (Merleau-Ponty, 2021), it is not a simple object, demeaning the very nature of relationship, but the place through which the subject is able to perceive and react to the environment, defining it as an "embodied subject."

The association of corporeality with the dynamics of technological innovation influences the construction of personal identity. A conscious perception of the body helps build a sense of self and could generate potential problems if not recognized as a true expression of a personal self. Models positioned within digital environments impose aesthetic standards that influence self-concept for an authentic process of self-recognition.

In posthumanism, the body is configured as a fluid space, not entirely stable but traversed by social, technological, and biological flows. Rosi Braidotti (2024) describes the body as a surface of intensity, capable of interacting with concrete and virtual experiences where biotechnology and digital devices expand the concept of experience. The body thus becomes a hub of interaction between the organic and the technological, where subjectivity mutates in a dynamic and relational process.

Promoting critical awareness allows us to see digital corporeality in a different light, leading us to focus on the nuances that foster the development of critical thinking. Pedagogy today faces a challenge it must be ready for, so as not to squander the educational potential inherent in new algorithmic devices.

2. Corporeality as a cognitive infrastructure in the post-digital era

The dimension of corporeality, as the result of a constitutive projection of cognitive and formative processes, has recently undergone a radical transformation accelerated by increasingly immersive, interactive, and multifactorial articulations of technological ecosystems. The phenomenological tradition (Merleau-Ponty, 2021) has structured these foundations for an understanding of "proximity" in the perception of one's own body, in its countless inferences and possible facets, as an embodied structure of meaning. For the most part, the contemporary social revolution, nourished by the cognitive sciences of the four "Es" (Embodied, Embedded, Enactive, and Extended), has provided a recalibration of the concept of the body and its epistemological meanings, considering them not exclusively as the "place" of perception, but as a dynamic device that contributes to the co-construction of meaning through distributed interactions between human and artificial agents in current sociocultural contexts.

From this initial analysis and construction of an approach to extended sensoriality, which accommodates apparatuses depleted of analytical-systemic

inferences, the vision of the body as a biologically formed instrument is embodied as a cognitive medium, which, operating through gestures, feelings, spatial orientations, and sensorimotor patterns, becomes both unavoidable and necessary. Precisely for this reason, international studies (Di Paolo, Thomposn, 2024) confirm that human cognition is the product of a situated, intercorporeal, relational, and profoundly material process.

The implications of the above question lead us to consider, from an educational perspective, that learning cannot be seen merely as a symbolic or abstract process of the interpretative representations we structure to understand, but must be analyzed as an embodied practice, as an experience lived through perception, movement, emotions, imagination, and social interaction. Therefore, if we consider the concept of corporeality, understood in its broadest sense, it must be reevaluated and supported by an organizing principle of the learning experience, capable of orienting attentional processes, modulating engagement, and supporting mnemonic load, facilitating the emergence of shared meanings.

The path currently being pursued focuses on corporeality as an epistemic resource, not a pre-digital remnant that acquires specific weight within intelligent technologies. Digital platforms, in fact, cannot exclude what the body represents in the surrounding world, precisely because they extend, transform, and recode it within a node of complex sociotechnical networks. The challenge today is to understand how the concept of corporeality, in all its complexity, can be rearticulated through technology-supported mediations that amplify some dimensions and attenuate others.

The question we ask today, and which becomes crucial in a proprioceptive perspective on personality related to the concept of the body, is: how is corporeality reconfigured when learning occurs in hybrid, immersive, and algorithmic environments? To answer this correctly, we must analyze the role of digital artifacts as embodiments of the human essence, sensory interfaces, wearable technologies, multimodal platforms, and the algorithmic infrastructures that substantiate the learning experience.

Digital mediation cannot serve as a sole channel for transmitting knowledge, but rather represents a revolutionary plan that restructures the ways in which the body perceives, is perceived, acts, and knows. Contemporary digital devices, from mobile devices to augmented reality platforms, from tracking systems to haptic interfaces, act as cognitive prosthetics, augmenting our perception of the body, making it technologically subservient, extending human sensorimotor and perceptive capacities in such a way as to increase the level of perceptive sensation and perception of reality.

In the hypermedia ecosystem, the body's function transforms into an active interface, that point of contact between multi-existential dimensions that characterize its physical and technological aspects. Research on the topic (Malafouris, 2019) has attracted great interest precisely because of the distributed nature of interactional flows, artifacts, environments, and intelligent algorithmic systems. The body should not be considered a barrier or obstacle to the management and acquisition of knowledge, but rather serves as a hub for an integration that involves a multimodal process.

Technological innovation appropriates the identity afferents that meticulously describe the condition of the extended and embodied body in cognitive approaches in technological environments. Indeed, this re-conditioning of the sense of belonging stemming from the existential awareness of the "body" and how it adapts to the world around it is based on a conceptual remediation that takes shape:

- ✓ Through a process that amplifies perception (AR, sensors, immersive viewers);
- ✓ By managing to extend action (Robotics built for educational activities, telepresence, and remote contact);
- ✓ By influencing attentional processes (adaptive interfaces, responsive environments);
- ✓ By revolutionizing memory (digital archives, algorithmic traces);

By restructuring sociality (virtual co-presence, interactions through associations through the use of social avatars).

Digital embodiment is brought about by an integrated, co-evolved mediation open to ongoing change. It trains on mechanical extensions through devices that intertwine introspective and proprioceptive modalities, where the body becomes the primary epistemic actor in mediated interactions.

Actors who move according to what is constructed, such as artifacts, devices, environments, and intelligent agents, which present themselves as simulated souls of bodily stimuli. Technological artifacts are trained to become one with the needs of human beings, representing the most significant point of union in today's educational process.

In the age of technological evolution, this form of embodiment translates into wearable devices, technologically sophisticated devices that can be worn or integrated into clothing. These tools can collect, analyze, and share data in real time, thanks to biometric sensors and wireless or Bluetooth connectivity. They thus represent an innovation of the Internet of Things (IoT), essentially a physio-technological relationship with objects and people in an interactive digital context.

These devices can extend the body's essence into a mystification of sensations that only the body can perceive and decode. This wearable perception finds application in a variety of fields:

- ✓ For well-being and health, through vital signs monitoring, disease prevention, and chronic disease management;
- ✓ For sports and fitness, through performance analysis, training planning, and recovery monitoring;
- ✓ For work and industry, providing support to workers with real-time instructions, environmental monitoring, and workplace safety;
- ✓ In the educational process and in augmented reality, through mobile and interactive learning tools.

This point is crucial for managing the perspectival phenomena of physical sensation, where the learning process takes shape and flows into the introspection of physiologically adapted phenomena. If the introduction of immersive digital environments has produced a cognitive conversion reflected in the embodied vision of the body as human elongation or articulation, the central point leans toward subjective requalification.

In contemporary adaptive systems, the use of mechanical devices such as social robots aims for active interaction, which is essential for building interdependent and socially necessary knowledge. These devices are autonomous or semi-autonomous machines designed to interact with humans and other agents, simulating social behaviors and creating emotional connections.

As artificial intelligence systems, they are empowered with autonomy thanks to sensors, cameras, and microphones capable of perceiving the environment and responding to human stimuli with gestures, expressions, and natural language, intelligently adapting to all social inferences. Physical fitness becomes paramount, forging emotional bonds with humans, attempting to embody emotional sensations and extremes. Their ability to read all verbal and nonverbal cues makes them adept at interpreting and decoding signals, proving themselves to be useful tools for solving potential health-related and other issues.

Tools for integrating bodily feedback, which extend and reimagine the notion of corporeality, such as AI devices for habit tracking, enable predictive analytics through algorithm training that generates results by embodying personalized insights to generate proactive suggestions. These include all those biofeedback devices designed to record internal bodily signals to offer self-training sessions for gradual stress reduction and performance improvement. These devices not only improve awareness of one's state of well-being, but also become flexible and broad-based

factors that encourage actions aimed at psychophysical well-being and a reworking of bodily needs that translate into mechanical applications.

Technological artifacts, therefore, cannot systematically act only as information mediators but can also convey emotions, feelings, and bodily states. Thanks to haptic inferences, for example, we can "feel" through digital information graded by vibrations, external and internal pressures, temperamental levels, and the fluctuating associations arising from character patterns. Consider examining how, at what level, bodily functions are transferred to the technological world by emulating its unique characteristics.

3. Learning and Digital Corporeality: Pedagogical Perspectives for Innovative Education

The relationship between learning and the concept of digital corporeality represents one of the most relevant epistemological issues in contemporary pedagogy. The complex of hybrid educational ecosystems, supported by a multitude of characteristics that determine their existence, has necessitated a rethinking of the role of the body in educational systems and processes. Far from being a residual particle from the period preceding the explosion of hypermedia applications, the concept of corporeality, borrowed from that technological sea, is configured as a cognitive intermediary, built on sensitive interfaces that direct the individual towards information flows for the construction of meaning. This meaning is oriented towards knowledge bulkheads, anchors of recognition for the sensorial activation of associative outputs, which encompass sensorial-representational and techno-sensorial events.

Forming and recognizing the stimuli that come from what the body displays can lead to a state and direction that positively transforms the human product. The mediating role assumed by technology must simultaneously fill the body's propositional and revolutionary void, which cannot easily depend on interpersonal extremism. The personalization of learning takes root through univocal practices that engage real voices and hypermedia devices.

In contemporary times, automated knowledge systems reflect the knowledge that comes from human inferences, but at the same time direct attention to those mechanisms of contextualized appropriation that index observed phenomena through data. It is worth remembering how pioneering studies (Hutchins, 1995, Clark & Chalmers, 1998) represented this social watershed by highlighting the importance of elements and contexts external to the human body in the cognitive processing process, focusing on the question of the brain's extension into the surrounding environment.

Digital environments have the ability to deceive human senses through the use of virtual reality platforms that facilitate the reinterpretation of corporeality. The synchronization of different bodily and digital communication channels acts as a version of reality as an extension of the body (Gehlen, 1980). The reference context considers the individual's agency as a necessary driver of knowledge in digital environments. When one actively interacts with digital environments, a system of embodiment is activated in which the virtual space becomes a genuine subjective experience

Fundamental in this context is the dual dimension through which our corporeal self interfaces with new automated systems. This involves the incarnation of the avatar, establishing an indissoluble bond between the subject and their technological alter ego, and the incorporation of infinite virtual space, lending the representation of the virtual body a sense of agency and ownership (Calleja, 2011). The dimension that transposes human features into hypermedia ecologies is composed of three components, the fulcrum of a mapping that forms the backbone of bodily extension:

- ✓ Self-localization, or the perception of being determined within the body;
- ✓ Agency, or the sensation of being the author of movements of a given body;
- ✓ Bodily ownership, identified as the perception that the body itself can represent the origin of lived experiences.

Literature shows how these dynamics, congruencies of sensory stimuli, can strengthen the idea of an alternative bodily identity by extending well beyond the boundaries imposed by the body structure in order to understand the environment made available following this extension with the aim of achieving a natural feeling of presence within it.

Today's educational context must deal with mechanical bodies that provoke reactions while attempting to best represent them. This process of adaptation to human needs allows algorithmic automation to reflect the corporeal nature of man, between biological conformations and mechanical authentication.

Currently, forms of social technology are moving in a very specific direction: the use of Artificial Intelligence in education, which has introduced a new condition for society: the coexistence of artificial agents with human agents in hybrid, but not fully defined, learning spaces characterized by sensory simulation and algorithmic inference. This issue extends to considering not only the opposition between technology and the body but their epistemic integration, where embodied learning does not disappear but takes on the characteristics typical of the human system.

With the advent of multimodal devices (Open AI, DeepMind, Meta AI), the key concept shifts attention to a new conception of corporeality, one that can be defined as synthetic. Artificial agents no longer process only text and content, but

also images, sounds, gestures, and sensory signals. This enables the creation of educational environments in which human corporeality interacts with artificial forms of sensation and the essence of corporeality, generating three types of emerging phenomena.

The first phenomenon is the construction of a simulated corporeality where intelligent avatars and virtual agents respond to human body movements, creating more complex sensorimotor interactions. The second phenomenon appears to be that of augmented corporeality, thanks to the implementation of sensors, haptic devices, and exoskeletons that enhance perceptual and motor capabilities, redefining the process of agency. The third and final phenomenon concerns the process that analyzes distributed corporeality precisely because cognition manifests itself through networks of human and artificial agents that generate forms of co-constructed and shared knowledge.

The concept of presence is redefined by the relationship between AI devices and the concept of corporeality: from the ability to perceive oneself in the environment to guide one's movement, to the control of the effectiveness of one's actions through a balance between interactions and outcomes, to the evolution of the self inherent in the definition of optimal experiences defined as flow experiences (Riva, G., 2009). Presence and virtual immersion therefore assume the role of guiding principles that assume a strategic and binding nature on the outcomes of the user experience, necessarily when emotions are the object of contention.

Presence is considered a key factor in eliciting emotional experiences, being able to manipulate both top-down and bottom-up components through a process of meaningful narrative. Furthermore, the concept of the nature of knowledge is being redefined precisely because the origin of knowledge becomes the cornerstone for a rethinking of knowledge.

Learning, which is embodied and digital, must generate and foster new skills, dictated by the need to navigate by sight, regulating human behaviors. Skills include multimodal literacy, which leads to the comprehension of knowledge from diverse application areas; algorithmic awareness, capable of interpreting it and elevating it beyond the mere intelligibility of datasets; the ability to develop co-action processes with artificial agents; and attention management in undefined, hybrid environments.

Conclusions

The transformations underway concern not only the integration of AI into educational processes, but also the need to move toward a conceptual and structural revolution that affects the very nature of artificial digital systems. The analysis conducted has shown how digital learning can be configured as an embodied

experience, which cannot be compressed or even designed without recognizing that current AI architectures, based on statistical models, disembodied representations, and abstract inferences, are still insufficient to support a truly situated, multimodal, and relational pedagogy.

The need for a fundamental shift, fundamentally embodied in AI architecture, must provide for the redevelopment of symbolic or vector representations lacking sensorimotor roots. This perspective must ensure that probabilistic inferences are not radically confined to algorithmically structured environments, where learning models fail to integrate contexts, bodily functions, and decision-making processes that often lack perceptual experience directly associated with the individual.

This condition becomes an educational paradox precisely because AI is often used today in educational contexts that require characteristics such as sensorial interaction, technological agency, and the extension of a corporeality that is not limited to the physical perimeter alone but constructs nuanced aggregations of meaning, remaining structurally disembodied for many of the actions constructed.

To overcome this impasse, we need to rethink the structure of AI architectures, orienting them toward an embodied revolution that takes into account several essential and fundamental aspects. These aspects must ensure an integral process that aims to recalibrate forms of relational inferences. These must be authenticated and oriented in contexts that are still unexplored and continually evolving. Education therefore becomes the laboratory environment that can foster and support this revolution, precisely because of its ability to require authentic and embodied interactions, to enhance the relational dimension, and to promote forms of distributed and collaborative learning supported by agency capable of understanding everything that revolves around the world around us.

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