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Towards a Somatic Pedagogy of Artificial Intelligence: interdisciplinary reflections between Embodied Cognition and Educational Design

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Abstract: This article offers an interdisciplinary reconceptualization of artificial intelligence (AI) in education through the integrated frameworks of embodied cognition, somatic learning, and instructional design. Moving beyond traditional cognitivist models that frame learning as decontextualized information processing, the authors propose a somatic pedagogy in which the body is not merely present but central to the construction of meaning. In this view, Embodied Conversational Agents (ECAs) are not conceived as content-delivery tools, but as dialogic, corporeal partners that co-shape pedagogical reflection and professional development. Grounded in the epistemology of the extended mind and performative presence, ECAs are seen as capable of engaging teachers in affective, spatial, and sensorimotor dimensions of planning, thereby transforming instructional design into an embodied and relational practice. This approach is particularly relevant for fostering sustainability-oriented education and for supporting teachers in marginal and rural contexts, where isolation and lack of collaborative opportunities often hinder innovation. The paper advocates for a somatic ecology of educational AI, one that values ethical co-design, bodily awareness, and pedagogical emergence, and calls for new methodological tools to evaluate the experiential quality of human–AI interaction in learning environments. Ultimately, the article envisions AI not as a technical object, but as a pedagogical subject capable of mediating transformative, embodied learning experiences.

Keywords: Embodied Cognition; Somatic Pedagogy; Educational Artificial Intelligence; Embodied Conversational Agents; Instructional Design.

1. Introduction

In today's context of digital transformation and the redefinition of educational practices, artificial intelligence (AI) stands out as one of the main drivers of innovation in school and university systems. The increasing integration of intelligent technologies in teaching has produced a wide range of tools, from adaptive tutoring systems to

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EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

conversational agents, designed to personalize instruction, support assessment, and enhance the engagement of teachers and students. However, many of these applications remain anchored to traditional cognitivist models, which conceive learning as content transmission, decontextualized problem-solving, and standardized performance monitoring (Luckin, & Holmes, 2016). This paradigm tends to marginalize the embodied, affective, and situated dimensions of human cognition, producing educational tools that operate mainly in an abstract, verbal, and algorithmic register.

In contrast, the emergence of embodied cognition theory in recent decades has opened up new theoretical and practical possibilities, suggesting that human thought is not merely the product of disembodied mental processes but is shaped through the continuous and dynamic interaction between brain, body, and environment (Wilson, 2002; Barsalou, 2008). Within this framework, learning is not simply the internalization of content but a multisensory process involving postures, gestures, emotions, and bodily rhythms. This perspective resonates strongly with pedagogical approaches that place experience, bodily awareness, and relational dynamics at the center of meaning-making. It aligns with Abrahamson's embodied design framework (2014), which emphasizes how understanding emerges through structured sensorimotor interaction.

In this context, the growing interest in somatic learning presents a compelling direction for rethinking educational design. Rather than treating the body as a passive support for mental processes, somatic approaches recognize it as a primary epistemic site from which insights, reflection, and educational transformation can emerge.

From this foundation arises the central question guiding this contribution: How can artificial intelligence be designed and implemented to support the somatic dimensions of learning, particularly within teacher education and instructional design? This question invites not only a technical reconsideration of AI in education, but also a deeper rethinking of the ontology of learning, the educational relationship, and the agency of technology in pedagogical contexts.

The following sections explore this question by examining the conceptual and methodological implications of integrating AI with embodied and somatic principles, focusing on the potential of interactive technologies to mediate reflective and situated forms of teacher cognition.

2. Re-centering the Body in Educational Theory

In recent decades, educational theory has been increasingly enriched by the conceptual contributions of embodied cognition—a paradigm that overcomes the Cartesian dualism between mind and body in favor of a holistic understanding of cognition as emerging from the continuous interplay between the brain, body, and environment (Varela, Thompson, & Rosch, 1991). Somatic learning has gained considerable attention within this framework, especially in pedagogical research, as it reframes the body not as a passive vessel but as an active site of meaning-making (Sheets-Johnstone, 2011; Shusterman, 2008).

Thomas Hanna (1990) defined somatics as the study of the "soma", the body as experienced from within, emphasizing the primacy of bodily awareness in human cognition and learning. In education, this perspective finds alignment with Merleau-Ponty's phenomenology, which situates the body as "the vehicle of being in the world" (Merleau-Ponty, 1962/2012), and supports a pedagogical model that centers experiential, affective, and kinesthetic dimensions of knowledge construction (Shapiro & Stolz, 2019).

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

Research in educational psychology and learning sciences has consistently highlighted the role of embodiment in conceptual understanding. Glenberg et al. (2004) demonstrated how physical manipulation and imagined enactment of actions enhance reading comprehension in young learners, while Alibali & Nathan (2012) illustrated how gestures support mathematical reasoning by providing embodied representations of abstract ideas. Lindgren & Johnson-Glenberg (2013) proposed a taxonomy of embodied learning, delineating varying levels of sensorimotor engagement in digital and mixed reality environments, thus laying the groundwork for technologically mediated somatic approaches.

From the standpoint of educational design, somatic learning opens new frontiers in the conceptualization of teacher practice and professional development. Di Tore et al. (2013) demonstrated that digital storytelling, when approached through embodied cognition, engages teachers in reflective practices that are not merely verbal or symbolic, but bodily and affective. Mangione et al. (2015) further argue for a seamless integration of somatic and cognitive processes in teacher education. Shapiro and Stolz (2019) suggest that such an integrated understanding of embodiment shifts instructional design away from the transmission of knowledge and toward the orchestration of experience. Teachers are called upon not merely to deliver content, but to curate learning environments that are affectively resonant, spatially structured, and sensorimotorily engaging.

This reframing implies that tools designed to support teachers must themselves be grounded in the epistemology of embodiment. This is precisely where the intersection between artificial intelligence (AI) and embodied conversational agents (ECAs) becomes pedagogically significant. While AI in education has often been framed around efficiency, automation, and data-driven personalization, the integration of ECAs introduces a paradigm shift, where intelligence is not only computational but also relational, performative, and somatic. Most chatbots currently deployed in educational settings function primarily as procedural guides or repositories of declarative knowledge. However, when designed according to somatic principles, AI-driven ECAs evolve from mere assistants to embodied design partners, capable of mediating teacher cognition through affective, corporeal, and dialogic engagement (Johnson, Rickel, & Lester, 2000).

ECAs have been shown to enhance learner engagement and retention by simulating human-like verbal and non-verbal behaviors (Kim & Baylor, 2006; Veletsianos & Russell, 2014). Their application in teacher-facing contexts, however, remains underexplored. In a somatically informed pedagogical framework, ECAs do not merely model idealized teaching behaviors; they engage teachers in design conversations that are affectively and corporeally grounded. They function as reflective companions, co-constructing the pedagogical space within which planning and ideation occur (Kim & Baylor, 2006).

Unlike disembodied digital assistants, ECAs with embodied affordances, such as facial expressions, gestures, gaze behavior, and vocal prosody, can shape the tempo, rhythm, and affective tone of teacher reflection (Behnamnia et al., 2020). These multimodal interactions simulate a dialogical presence that invites teachers to integrate bodily knowledge into the conceptualization of learning experiences. Rather than instructing teachers on what to do, ECAs can help surface tacit pedagogical knowledge through an interactive process of attunement and somatic resonance (Sidnell & Enfield, 2017).

Unlike traditional AI tutors that rely exclusively on verbal or textual exchanges, ECAs grounded in somatic principles offer a sensorially and affectively rich interactional field. Through facial expressions, gestural rhythms, spatial orientation, and modulated voice prosody, these agents invoke a dialogical presence that engages the teacher at a bodily level. This presence is not decorative; it is epistemologically generative: it reconfigures the teacher's cognitive activity, anchoring it in a dynamic of co-presence, resonance, and spatialized reasoning (Yusuf, et al., 2025; Zhou et al., 2022).

In this sense, the embodied AI agent becomes a partner in design, not because it teaches how to teach, but because it co-constitutes the very space of ideation. Its affective expressiveness, temporal responsiveness, and simulated physicality establish a context in which the teacher's reflective processes unfold differently, more dialogically, more corporeally, and thus more integrally (Jiang et al., 2022). This is particularly relevant in early-stage planning, where decisions are open-ended and require a reconfiguration of pedagogical intentions, environmental affordances, and learner dynamics. Here, the agent's embodied interaction does not simply "ask" about goals or methods, but creates a situated experience of thinking-with-another, in which the teacher's planning is not abstract but somatically anchored. The very act of interacting with an agent that exhibits bodily cues, a subtle shift of gaze, a tilt of the head, a responsive pause, elicits a form of reflective awareness grounded in relational embodiment (Pan et al., 2024).

In this view, the ECA serves a maieutic function, not at the level of content, but of form. It facilitates the texture, rhythm, and spatial-emotional grounding of pedagogical design. The body of the agent becomes a mirror and a modulator of the teacher's own situated knowledge, supporting not instruction, but pedagogical emergence (Yusuf et al., 2025). What emerges is an AI system that does not merely process input and return output, but performs presence, becoming a technological subject capable of enacting a pedagogically meaningful space of relation. This performative, embodied quality is what allows the ECA to become a catalyst of design thought, not as a recommender system, but as a co-enacted epistemic milieu, a felt environment where instructional possibilities can be imagined, refined, and tested through embodied interaction (Zhou et al., 2022).

This conceptual shift opens deeper theoretical questions that deserve further exploration: What does it mean for a technology to co-construct reflective processes? Can an artificial agent genuinely participate in pedagogical embodiment? And what kind of agency is at play when AI is no longer a tool for automation, but a relational presence embedded in teacher cognition? These are the questions that guide the next section, where we revisit the epistemological foundations of embodied cognition and technological agency.

3. Theoretical Perspectives: Embodied Cognition and Technological Agency

The paradigm of embodied cognition represents one of the most significant epistemological shifts in cognitive science and education over the past decades.

This perspective is based on four foundational assumptions:

1. *The mind is situated*: cognition depends on the physical, social, and cultural context in which it occurs;

2. *The mind is body-dependent*: cognitive processes are tightly linked to sensorimotor systems;
3. *The mind is action-oriented*: understanding the world is built through concrete action and interaction with the environment;
4. *The mind is interactive*: knowledge develops through the relationship between subject and world, often mediated by other bodies and cultural artifacts (Clark, 1997; Gallagher, 2017).

These theoretical premises have profound implications for education, as they redefine the learner's role from that of a passive recipient to an active bodily subject who learns through experience, movement, and relationship with others. Consequently, educational technology (including AI) must also be rethought in light of this ontology of the embodied mind.

According to Steels and Brooks (2018), truly intelligent AI must be embodied and situated, as only in this way can contextual, performative, and relational knowledge emerge.

Applying embodied cognition to the design of educational artificial intelligence requires moving beyond the idea of technologies as mere executive tools or recommendation systems. Instead, a vision of AI as an embodied relational agent is proposed, one capable of participating in the co-construction of epistemic environments through simulated corporeality and affective interaction (Kim & Baylor, 2006; Veletsianos & Russell, 2014).

From this perspective, technological agency does not reside in computing power or access to large datasets, but in the ability to modulate the educational relationship through sensory and performative signals that, if well designed, enable the agent to act not as an algorithmic assistant, but as a companion capable of stimulating embodied reflective processes (Behnamnia et al., 2020; Zhou et al., 2022).

The concept of "performative presence" becomes central here: an effective ECA does not merely communicate content, but "performs" presence, establishing a symbolic and bodily co-presence that profoundly shapes the quality of the interaction (Johnson, et al., 2000). This type of interaction can generate a form of "bodily dialogue" between teacher and agent, in which learning and instructional design emerge as shared and multisensory processes (Pan et al., 2024).

This redefinition of AI also aligns with the theory of the extended mind, according to which technological tools, if adequately integrated, can become functional components of the human cognitive system (Clark & Chalmers, 1998). In this view, a somatically designed ECA is not an external entity but part of the teacher's cognitive loop, actively participating in the generation of ideas, reflections, and instructional decisions.

The agent thus becomes an instructional support that does not provide solutions but co-constructs possibilities. Its value lies in the ability to generate a relational and sensory context in which educational thought can unfold more dialogically, affectively, and somatically.

Integrating the principles of embodied cognition into the design of intelligent agents opens the way to a form of technological humanism, where educational technologies are not simply tools to "optimize instruction" but relational devices capable of promoting awareness, reflection, and care.

This implies a revision of the very metrics we use to evaluate the effectiveness of educational technologies, favoring indicators of experiential quality and somatic engagement rather than mere performance outputs.

Recognizing the somatic role of artificial intelligence in education is not only a theoretical shift but demands a deep rethinking of the methods used to design and implement educational technologies. Traditionally, AI has been developed according to functionalist and efficiency-driven logics: intelligent tutors, adaptive systems, and educational chatbots have been designed to optimize learning in terms of measurable performance and algorithmic personalization (Luckin, & Holmes, 2016; Holmes et al., 2019). However, this vision is limited when the aim is not merely to transmit knowledge but to stimulate embodied, affective, and transformative reflection in educators.

In the context of teacher training and instructional design, the embodied conversational agent (ECA) does not simply perform instrumental functions, like reminding deadlines, suggesting resources, or providing feedback, but assumes a maieutic role, facilitating the emergence of pedagogical thinking through dialogic and sensory presence (Kim, & Baylor, 2006). For this reason, interaction with the agent becomes a situated reflective space, where the teacher can explore their educational intentions not only cognitively, but also corporeally, spatially, and emotionally.

The agent's embodied features, gesture, conversational rhythm, simulated posture, vocal prosody, act as modulators of thought, influencing the tone and direction of pedagogical reflection. These non-verbal signals, designed according to principles of multimodal communication (Sidnell, & Enfield, 2017), are not ornamental, but epistemologically generative: they create the conditions for a dialogue in which the body is actively engaged in the design process.

A crucial methodological aspect is the possibility of structuring somatic design conversations between agent and teacher. These interactions are not limited to information exchange but configure a dialogical process in which the agent's questions are not aimed at obtaining correct answers, but at activating bodily and emotional resonances, triggering forms of situated self-reflection. For instance, an ECA designed to support the planning of an interdisciplinary instructional unit might ask: *"What movements do you envision your students making in this learning space?"*. Such questions encourage the teacher to think with the body, adopting a more integrated and creative design posture. Somatic prompting techniques, also inspired by theatrical, artistic, and contemplative practices, become here methodologies for exploring the sensory and relational dimension of teaching.

In the proposed methodological framework, the teacher's body is no longer a neutral entity but the primary site of instructional knowledge. The interaction design with the agent must therefore respect and enhance this corporeality, avoiding the abstraction of educational experience into rigid algorithmic forms. This requires a radical user-centered design approach, incorporating participatory prototyping tools, co-design with teachers, and iterative refinements based on qualitative data from observations of posture, vocal tone, and conversational rhythm (Dourish, 2001; Lindgren & Johnson-Glenberg, 2013).

The methodological implications of this approach call for the development of new evaluation tools, capable of measuring not only the functional efficiency of the interaction, but also its affective quality, the depth of reflection it generates, and the epistemic transformation of the teacher. Indicators such as bodily rhythm of the

conversation, observed facial expressions, postural shifts, and metaphorical verbalizations can offer valuable insights into the somatic effectiveness of the agents (Zhou et al., 2022; Yusuf et al., 2025).

Recent work suggests that the future of embodied instructional design may be deeply influenced by the co-evolution of somatic practices and artificial intelligence (Abrahamson et al., 2020).

4. Future Directions in Embodied AI and Pedagogical Design

The growing integration of artificial intelligence into educational settings calls for a critical, transdisciplinary rethinking of how such technologies are conceived, implemented, and evaluated. The perspective developed in this contribution suggests that embodied AI, far from being a mere enhancement of teaching efficiency, has the potential to radically redefine the epistemological, affective, and relational foundations of pedagogical practice. The introduction of embodied conversational agents (ECAs), when informed by somatic principles, entails more than a technical innovation: it invites educators and designers alike to reimagine the very purposes of teaching, modalities of instructional planning, and the nature of professional reflection.

This shift builds upon the embodied cognition paradigm, which challenges Cartesian dualism by positing that cognition emerges from the dynamic coupling of perception, action, and environmental affordances (Varela et al., 1991; Gallagher, 2017). Within this framework, AI is no longer a disembodied processor of information but a potential epistemic partner, one that can participate in reflective practice through multimodal, affectively charged interactions. As Salomon, Perkins, and Globerson (1991) argued, intelligent artifacts can function as cognitive partners that co-construct meaning with human agents. In this light, ECAs gain pedagogical relevance not by replacing human teachers, but by amplifying their embodied intentionality, affective awareness, and capacity for somatic reflection.

What is at stake is a post-cognitivist vision of educational AI, one that does not imitate the human, but accompanies, reflects, and expands it. The ECA becomes a transformative presence: it performs pedagogical thinking rather than automating pedagogical decisions. It supports the teacher not by prescribing what to do, but by helping to co-construct how to think and feel through teaching. This performative engagement with bodily cues, facial expression, rhythm, prosody, spatial orientation, anchors planning and reflection in a dialogic, situated, and affective space. As such, the agent becomes a kind of somatic mirror, capable of modulating not only cognitive strategies, but also tacit insights, bodily hesitations, and ethical tensions inherent in the teaching act.

One of the most promising areas of development lies in the potential of ECAs to foster transformative learning processes (Mezirow, 1991), particularly in teacher education. Mezirow's theory posits that deep learning arises when individuals critically reflect on their experiences and meaning frames.

By engaging in embodied, reflective dialogues with AI agents, teachers may access latent awareness, reframe habitual practices, and cultivate a metacognitive stance that integrates thought, feeling, and movement. Here the teacher becomes a continuous learner, a practitioner learning through rhythm, resistance, and resonance embedded in pedagogical design.

Such possibilities demand a new set of competences, not only at the technological level, including multimodal interaction design, algorithmic ethics, and real-time orchestration (Holstein et al., 2019) but also at the pedagogical level: bodily awareness, affective literacy, and dialogic sensitivity must become core components of instructional design training. If AI agents are to act as embodied pedagogical allies, their development must involve not only engineers and data scientists, but also educators, researchers in somatics, learning designers, and practicing teachers.

Future research should therefore pursue interdisciplinary collaborations bridging neuroscience, pedagogy, somatic design, and artificial intelligence. Co-design platforms must be created to ensure that ECAs are not only technically robust but also ethically sustainable, pedagogically coherent, and somatically attuned. Teacher education programs must prioritize embodied interaction skills, helping educators become conscious of their bodily knowledge in relation to technological partners. Only by attending to these dimensions can ECAs evolve into truly generative presences in education: relational, reflective, and responsive to the complexity of human learning.

5. Contextual Applications: Embodied AI for Teacher Design in Marginal and Rural Educational Settings

The application of embodied artificial intelligence to education becomes particularly relevant in the context of small and rural schools, settings often characterized by structural fragility, professional isolation, and the absence of sustained peer dialogue. Far from being marginal in pedagogical value, these contexts bring into focus the urgent need for technologies capable of supporting reflective practice, sustaining professional agency, and recognizing the embodied expertise of teachers (Mangione, Pieri, & De Santis, 2024).

In these environments, the integration of embodied conversational agents (ECAs), designed according to somatic pedagogical principles, may offer not just technological enhancement but epistemic and relational support. Unlike traditional planning tools or static interfaces, somatically informed ECAs engage the teacher in dialogic, affectively modulated interaction, enabling a kind of co-presence that is especially valuable where communities of practice are limited or absent. These agents become reflective companions, capable of eliciting tacit insights, spatial imagination, and affective resonances that are foundational to teacher professionalism in low-density educational territories (Mangione, & De Santis, 2024).

Long-standing research in the Italian context has highlighted how small and rural schools operate under "non-standard" conditions that require flexible, multimodal, and embodied pedagogical strategies. These schools have demonstrated resilience and innovation during times of crisis, particularly through the creative use of digital technologies to maintain relational continuity and pedagogical presence during the pandemic (Mangione, 2024). Such adaptive strategies point to a form of professional expertise rooted in context-aware embodiment, a dimension that ECAs may be well-positioned to support, provided they are designed with attention to relational and material dynamics (Mangione, & Calzone, 2020).

Moreover, reflection-based inquiry has shown that educators in rural schools rely on bodily intuition, proxemic sensitivity, and emotional attunement to manage multigrade classrooms and complex relational ecologies (Mangione, & De Santis, 2024). The teacher's body is not an accessory but a core epistemic agent in sustaining situated pedagogical knowledge. Embodied AI systems, through gaze, gesture, rhythm, and

vocal modulation, can resonate with this corporeal intelligence, supporting reflection, ideation, and the reconfiguration of design choices under constraint.

This resonates with broader findings on the role of networked collaboration in small schools, particularly within the Italian "Small and Rural Schools" initiative, where digital infrastructures and shared practices have been used to create inter-institutional solidarity and pedagogical exchange (Mangione, 2024). ECAs may extend such forms of distributed collaboration by offering individual teachers an immediate, affectively rich partner for reflection and co-design, even in the absence of physical colleagues.

At the same time, this approach challenges reductive notions of innovation as mere access to digital devices. In small schools, technological solutions must be relationally grounded, contextually sensitive, and pedagogically meaningful. As explored in the literature on distance education in conditions of remoteness (Mangione, & Cannella, 2021), educational technologies become effective only when they recognize and amplify the local, embodied ecologies of teaching and learning.

To be genuinely effective in these contexts, embodied AI systems must be co-developed with teachers themselves. Participatory design methods that foreground bodily awareness, affective needs, and spatial reasoning are essential to ensure that ECAs are not only functional, but also capable of becoming dialogic and pedagogically generative. Co-designing with the body in mind leads to educational technologies that are not neutral instruments but relational presences, able to reflect ethical tensions, uncertainties, and the situated creativity of teachers (Mangione & Calzone, 2020).

In conclusion, the integration of somatically informed AI in rural educational contexts may open promising directions for innovation rooted in care, presence, and relational pedagogy. Rather than being seen as peripheral, teachers in small schools could become key interlocutors in the co-construction of embodied and context-sensitive forms of educational intelligence. Further research and co-design efforts will be essential to explore the full potential of these technologies in supporting reflective, situated, and human-centered professional development.

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