‘If you can’t dance your program, you can’t write it’ [1] : Challenges and Implications for AI in Education

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Abstract

This article offers a critical analysis of the role of the body in the development of artificial intelligence (AI) in the field of education. It challenges the dominance of symbolic and disembodied AI models based on abstract information processing and advocates for a paradigm shift toward embodied AI grounded in situationality, emergence, and sensorimotor coupling. Drawing on post-cognitivist frameworks, the article highlights the cognitive and experiential limitations of current GenAI systems, such as the loss of proprioception, multimodal agency, and the devaluation of embodied practices. It proposes a redefinition of Human–Computer Interaction (HCI) centered on a perceptual–affective choreography. The article advances a more inclusive and emancipatory vision of AI in education, aimed at fostering creative, critical, and situated learning through a set of embodied design principles.

Introduction

This article addresses the pressing question of how to incorporate, in a principled way, contemporary AI resources into pedagogical approaches. This is a problem for all age groups elementary through tertiary in USA K-12 and ‘college’ and much of the educational curricula worldwide. The position of authors is that human pedagogy is rooted in shared, embodied experience, and this ‘performative idiom’ [2] [1] is at odds with the fundamentally ‘representational’ modality of ‘knowledge’ or ‘information’ characteristic of digital computing and AI. This ‘representational idiom’ is premised on the assumption of the possibility of separation between materiality and information.[3] We draw on theories of embodied and cognition to question this separation. We argue that there is an ontological divide between embodied, enactive, situated, materially engaged conceptions of cognition and cognitivist/computationalist conceptions of cognition. This ontological divide has direct bearing on understandings of pedagogy, and in-particular on appropriate deployment AI in pedagogical contexts. These issues are explored below.

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[1] Veteran coder and internet pioneer Tom Jennings gave this advice to coding students at UCI, when he was part of the (now defunct) Arts Computation Engineering graduate program.

[2] Pickering, A. The Mangle of Practice.

[3] The term ‘representational’ has varying definitions. Here it is used in the cognitivist/computationalist sense: “symbolic phenomena upon which cognition or computing is performed”. In human cognition these arrays of symbols are taken to be ‘mental’ (in the ‘Cartesian theater’). In computing they are taken to reside in symbolic arrays in code.

Generative AI's application in education has been positively received by advocates of transmissive or "banking"[4] pedagogies [2], platforms such as GPT-4, Leonardo, Gemini, and DALL-E are increasingly used for text and image production. However, the intensive use of Large Language Models (LLMs) like ChatGPT in educational contexts may lead to an "accumulation of cognitive debt" that weakens critical thinking and epistemic ownership [3][5]. Such research suggests LLMs users exhibit lower brain connectivity, reduced intellectual engagement, and difficulty citing their own ideas, suggesting that the efficiency provided by these tools may be negatively reshaping deep learning processes and intellectual autonomy, leading to concerns about cognitive deskilling and dependency. Similarly, recent research on the creative potential of generative AI in textual and artistic production highlights the limitations of these systems in capturing the human complexity of creativity, particularly its novel dimension [4]. In creative contexts, GenAi use tends to have the effect of 'regression to the mean' - less skilled users 'improve' but higher skilled users decline. In the below, we explore the challenges and implications of AI in education by introducing the term *Embodied AI.* This seems like an oxymoron, and this is precisely the point.

1. Why embodied AI?

The growing interest in embodied skill development in education, particularly in the formation of concepts and metaphors, challenges transmissive and disembodied pedagogical views of cognition [5]. At the same time, digital learning (in the form of corporate online packages that emulate 'content-delivery', 'teach-to-the-test' styles of pedagogy, especially with the support of GenAi, threaten the growing interest in the body and the material in learning. We need a way to reconcile this divide.

AI lacks a body and lacks a material form. We wish to draw attention to this self-evident fact because it has a significant impact on the forms of knowledge that AI draws on, with implications for the knowledge that is transmitted down the line. Humans interpret phenomena in the world via direct sensorial experience - this is a major way in which humans come to 'know' things [6]. Digital systems in general, of which AI is a kind, have access only to pre-processed symbolic content. Whether they can be said to 'know anything' or 'have experiences' is a philosophical problem that has dogged AI discourse for half a century. We (the authors) would answer that question regarding the capacity of AI to demonstrate experiential knowledge, provisionally in the negative. The most common form of AI is language-based. This privileges forms of knowledge that can be expressed semantically and erases the more tacit forms of knowing that an engaged classroom promotes. It returns the classroom to the space of abstracted forms of knowing, based in classical symbolic manipulation [7]. Artificial Intelligence is artificial precisely because it operates in this abstracted arena. Embodied AI, which posits that intelligent behavior emerges from physical interactions with the environment, offers a compelling framework for understanding learning as an embodied process. Any (materially engaged) skill acquisition (playing piano or fly-fishing) is inherently autodidactic a teacher can only provide 'nudges'.[6]

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[4] The banking model of education is a traditional and top-down pedagogical approach in which knowledge is conceived as a deposit that the teacher "transfers" to students. This approach denies the learner's agency by limiting their critical capacity and restricting their participatory engagement in the process of sense-making and joint praxis.

[5] See also https://time.com/7295195/ai-chatgpt-google-learning-school/ (accessed 18june25).

[6] See David Sudnow, Ways of the Hand. MIT 1993. Se also Penny, S. Skill (forthcoming).

"*We may hope that machines will eventually compete with men in all purely intellectual fields. But which are the best ones to start with? Even this is a difficult decision. Many people think that a very abstract activity, like the playing of chess, would be best. It can also be maintained that it is best to provide the machine with the best sense organs that money can buy, and then teach it to understand and speak English. This process could follow the normal teaching of a child. Things would be pointed out and named, etc. Again, I do not know what the right answer is, but I think both approaches should be tried.*" Alan Turing, Computing Machinery and Intelligence [8].

Turing [8] insightfully outlined two approaches that could characterize an intelligent machine: (i) teaching machines through abstract rules, as in chess, and (ii) equipping them with advanced sensors and training them like a child. A relevant point for discussion is that Turing draws an analogy between intelligence and the ability to teach and learn a language, inferring a transmissive educational approach by reducing the educational process to pointing and naming things. This is consistent with current AI models, which, while evolving in capabilities and interfaces, still adhere to principles of goal-oriented behavior based on pre-existing information. This stands in contrast to how the behavior of both human and non-human organisms' functions. While Turing [8] reflected on the necessity for machines to be "embodied" in order to develop certain forms of intelligence, such as language learning, he preferred to focus on symbolic aspects like games and cryptography because they required less interaction with the physical world. This is similar to what many formal educational systems aim for, through their cognitivist curricula and pedagogical implementation of their educational plans.

Penny [9] argues that from its inception, "Artificial Intelligence" was informed by the Cold-War mentality of imminent threat. The name of the field is a rather grand claim - a more honest name would be "automated reasoning," given the vast differences between artificial machines and living machines [10]. This is seen in the foundations laid out by Maturana and Varela [11] regarding the basic principles that govern living machines (self-organization, autonomy, structural determinism, structural coupling, natural drift, and the anti-teleology of living systems). Among Artificial Life researchers, the distinction was made between 'hard alifers' and soft alifers': the former held that "digital organisms were living beings", the latter held that "digital systems could simulate some qualities of living systems" [9]. This distinction was based on a similar division in AI, between "hard AI" and "soft AI" viz: AI is intelligence vs AI simulates intelligence.

Currently, artificial intelligence is conceived as generative *GenAi* or agents conditioned by specific requirements or "prompts," designed to generate responses to various problems and needs. The OECD [12] defines AI as a computational system that, based on explicit or implicit objectives, infers from the input data it receives how to generate results such as predictions, content, recommendations, or decisions, which can influence both physical and virtual environments. Through AI platforms like Chat GPT, Gemini, Leonardo, Midjourney, and others, it is possible to execute a variety of requests, ranging from generating images and texts to animating audible objects and automating devices. These AI systems consist of Multimodal Deep Learning that allow them to learn passively by processing vast amounts of data without direct interaction with the environment. To achieve this, they use deep neural networks, backpropagation algorithms, and evolutionary algorithms to adjust parameters and minimize errors. Although LLMs have an impressive capacity to automate processes and generate convincing texts, they are (famously) not exempt from 'hallucination' in their autonomous learning. This is due to their passive training process, based on the statistical prediction of patterns from vast volumes of historical data, without a deep understanding of the environment and its interaction with it. The nature of artificial intelligence systems lies in their algorithmic and stochastic structure, where learning from the past governs their action paths, without the ability to transform their environment or exhibit dynamic adaptability in real time.

Andrej Karpathy [13], a renowned AI programmer at Tesla, reports that training neural networks is a complex and error-prone process, and the apparent simplicity in libraries and frameworks conceals the inherent difficulty of configuring models correctly. The complexity of emulating even non-human behaviors, such as humpback whale hunting or the courtship display of the Japanese pufferfish, can lead to "leaky abstractions." The fact that a system can correctly recognize and label a "dog on a surfboard" does not mean that it comprehends the physical coherences represented in such images (hence the surreal images of three armed children and so on). Perceiving is not just about identifying visual patterns; it is about living and situating those patterns within a continuous flow of (physical, embodied) experience. While AI can correlate visual and linguistic data, it does not "see" or "understand" the scene as an embodied being would. "Hallucinations" and the tendency of LLMs to generate unfounded erroneous responses are a direct consequence of this pattern-based approach, which lacks real world validation, or the opportunities for action that active agents offer [14]. The technology that we are invited to call "artificial intelligence" is based on a deeply reductionist view, borrowed from a philosophical tradition that conceives intelligence as the manipulation and communication of symbols, a strictly logical and abstract process [15].

Can a system of information automation based in a dualist ontology that separates 'intellect' from 'experience' have relevance within a pedagogy that finds embodied experience fundamental to (valid) learning? Intelligence, far from being merely automated reasoning, emerges from direct interaction with phenomena, in a continuous and dynamic process that goes beyond the rigidity of symbolic representations. What much of the AI used in various contexts, especially in education, does is utilize "stochastic parrots," incapable of understanding the meaning of relationships between data beyond their mere correlation. This can lead to unprecedented consequences based on the trust and biases that AI can produce in educational implementation. In contrast, a focus on Embodied AI goes beyond this. The educational implications of Embodied AI revolve around two key aspects: (i) designing AI systems capable of generating their own domains of relevant interactions; and (ii) supporting, regulating, and enhancing skills within contextually grounded practical engagements.

2. Importance of the body in the new age of AI

Since its origins at the 1956 Dartmouth Conference, AI has been developed within a symbolic paradigm, focused on the manipulation of abstract representations and logical search systems [16]. This is what Van Rooj and colleagues term “AI qua information processing psychology” [17] and it is important to note the interdependence between the two concepts leads to a profound circularity in thinking. The influence of computer architecture, particularly the Von Neumann model, has profoundly shaped the way researchers conceptualize AI, pushing it toward unrealistic approaches disconnected from the physical world. Starting in the 1980s, an alternative approach known as embodied AI or behavior-based robotics emerged [18]. Key concepts such as situatedness, embodiment, and emergence reshaped the foundations of intelligence, prioritizing agents that operate in real-time without relying on complete internal models [19]. Embodiment forces designers to confront the complexity of the physical world and provides a foundation for moving away from symbolic representations within an agent, emphasizing the importance of describing the relationships that matter [20]. This theoretical and practical evolution suggests a paradigm more aligned with biological behavior, where knowledge is constructed from and through embodied experience, rather than through an objective model separated from the agent [21]. Brooks [18] proposed an incremental, real-world-based approach, building autonomous robots that operate without the need for centralized internal representations - contradicting the received wisdom of internal modelling and planning, saying 'the world is its own best model'. This 'subsumption architecture' consist of layers of activity that directly connect perception with action, enabling more robust and adaptable systems. Indeed, current challenges in humanoid robotics still center on decentralizing structures to favor emerging sensorimotor couplings with the physical environment.

Special attention should be paid to past criticisms regarding the sensorimotor debilities in interactions with digital technologies, particularly in GenAi, which reflect a profound disconnection from the embodied richness of human experience [9]. These debilities manifest as a loss of multimodal agency, weakening the sense of proprioception, kinesthetic awareness, and tactile engagement that emerge from being alive, moving, and sensorially interacting with the world. The devaluation of craftsmanship or do-it-yourself (DIY) making practices further contributes to the erosion of aesthetic and experiential dimensions, which are intimately tied to acting, feeling, and generating meaning through movement.We believe that the lack of impetus to build on an embodied programme of research in AI will lead to impoverished educational experiences as AI is more widely employed in education. Post-cognitivist research, including frameworks such as 4E (embodied, enactive, embedded, extended) and SEEED (situated, embodied, enactive, embedded, distributed), has addressed these issues in educational technology, see Glenberg [22], Penny [15], Abrahamson [23], Aguayo et al. [24], Videla et al. [25] and we call for greater focus on these.

The embodied cognition posits that knowledge is based on interactions between the body and the environment, with a strong sensorimotor foundation that precedes symbolic language [26, 27]. Enactive cognition emphasizes that knowledge arises from a dynamic coupling between the organism and the environment, through the experience of meaning-making without relying on mental representations or a pre-established world [20, 28]. Embedded cognition holds that knowledge arises in structured environments that support specialized practices intertwined with material and technological elements [29, 30]. Extended cognition asserts that knowledge extends beyond the body to external artifacts, based on shared functional processes between agents and their environment [31, 32]. This embodied perspective directly challenges conventional computing education, which remains rooted in symbolic manipulation, neglecting the role of corporeality and agency. By ignoring the sensorimotor foundations of human cognition, traditional computing pedagogy reinforces a limited, decontextualized model of intelligence.

These post-cognitivist perspectives allow for a redefinition of Human–Computer Interaction (HCI) through Embodied AI, which involves questioning not only interfaces and devices, but also the ontological and epistemological conceptions of what it means to be human in a technologically mediated world. From this standpoint, the body is not a secondary or peripheral interface, but the constitutive core of thought. This view is closely aligned with a profound critique of the dominant paradigm in HCI, as articulated by John Seberger [33] , who argues that the "human" for whom HCI is designed is simultaneously a human designed by HCI itself. In this sense, a tautological figure is produced: a certain conception of the generic user (efficient, rational, instrumental) is assumed, and by designing for this user, that very conception is reinforced and naturalized. The result is an "unmarked human," functional to logics of efficiency, data extraction, and standardization, excluding bodies, experiences, and expressions that fall outside of this framework. In the face of a daily life increasingly structured by instrumentalized gestures, there is a pressing need to design technologies that shift AI's reliance on vision and text toward a perceptual–affective choreography, where interaction is lived, embodied, and negotiated in real time. Only then can AI in education become a medium for emancipation (critical, creative, and collaborative) rather than, as Seberger describes, an infrastructure with fangs: a structure that bites, normalizes, excludes, and reproduces impoverished ways of living in the name of efficiency.

3. AI and creativity and how this ties into these linear and disembodied assumptions from education.

When Guilford[7] addressed the American Psychological Association in 1950 and encouraged them to focus more on what makes the everyday person creative, part of his worries stemmed from the rise of automation and what this meant for the workforce. His argument was that machines would replace manual and automatic labour processes, but creative thought should be nurtured as something which is irreplaceable. Today, AI appears to be replacing many of the more 'informational' skills he sought to preserve, but the question of whether AI can be creative remains a lively debate.

The anxiety around generative AI and creativity reflects the anxieties of a transmissive education system. First, the importance of the process of creativity is ignored. The product is evaluated as better or worse. If the final product is evaluated as being worse when produced by a human agent, then the human agent will be relieved of the task of creating. The transactional nature of this exchange – it is cheaper and more effective to use AI – ignores the human benefits of the process of creating. This is particularly important when we see how creativity flourishes in the classroom and brings with it benefits far beyond the final product. This model of creativity is one which would terms the efficiency model. That is, the focus is on the benefits of the product, rather than the benefits of creating. It is rooted in internalist perspectives on creativity which ignore the embodied and material implementations of initial ideas [34]. This model of creativity when applied to the AI-human creativity competition echoes a neoliberal model that places outcomes over process. However, the process of creating is an important aspect of development across the lifespan. Through creating, human agents can engage in deep seated learning and the development of curiosity, self-efficacy and resilience.

Creative invention is a form of intelligent play. It often occurs in collaboration with materials and leads to forms of tacit knowledge that cannot be easily emulated in a traditional classroom, such as bricolage, serendipity, and improvisation. Take, for example, a pot made by an amateur and given as a gift to their mother. With a 3D printer and a generative AI bot, one could produce a pot that appears to be creative, simply from a text prompt, interpreted by the AI tool based on all the examples available to it of 'pots' which may include chamber pots, lobster pots and pot-bellies. This could result in grotesque gifts for mother). Inspired by the philosophical concept coined by Slavoj Žižek, the exhibition "Organs without Bodies: Generating physical objects with AI"[8] [35] invites critical reflection on a world where everyday objects like teapots,

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[7] The president of the American Psychological Association who is widely credited with initiating the boom in creativity research with his speech urging psychologists to take creativity seriously.

[8] Riffing on the Deleuzian 'Body without Organs'.

plates, and cutlery can be generated without the "bodies" of artisans, designers, or mass production systems. It raises questions such as: What will be the role of humans in creation? What should education re-signify so that the limitations of these models do not end up dictating human meaning and reinforcing biases? The incorporation of the embodied cognition approach, which highlights the role of bodily practices in understanding and creating ideas, challenges the transmissive educational model reinforced by GenAi, overcoming the limitations of machine learning systems that generate objects solely from text. The mark of the human requires an intuitive understanding which runs counter to the transmissive model of education in which all knowledge can be easily articulated.

The simple resolution to this is that AI, by its nature, samples cases identified as being in a specific genre, in order to generate variations *within a specified domain*. This is what Peter Cariani [36] dubbed 'combinatorial creativity' a quarter century ago. [9] A characteristic of more substantial creativity - in art as well as in science - is that it challenges the definition of the domain itself. Second, the use of mainly language based generative AI (although we acknowledge video and picture-based versions) returns the nature of creativity back to the level of the idea - and a word-based idea at that. This is in line with most research in creativity which measures human creativity through language-based games and then uses performance on this task as an indicator of creative potential. This is despite there being a difference between what Weisberg terms *in vitro* and *in vivo* creativity [37, 38]. In addition, this reinforces a hierarchy of knowledge that separates *episteme* and *techne* and privileges the abstract knowledge over the concrete knowledge. This is reinforced by a lingering Cartesian split between the knowledge held in the head and that held in the practice of the body. For example, in science since the founding of the Royal Academy, a distinction has been made between the investigator that comes up with the ideas and the research assistant that implements them [39]. It is this hierarchy of knowledge which privileges the importance of ideas created through LLMs rather than ideas implemented and developed by humans. It is also that hierarchy of knowledge that continues to ignore the body and the material world in education. GenAi poses a threat to education because it continues to cast creativity in this mold.

4. Embodied AI applied in education: Design principles

As we have outlined in the previous paragraphs, the post-cognitivist principles of embodiment, situationality and anti-representationalism provide a fundamental framework for rethinking GenAi in education. In this context, it is key to focus on embodied educational design, which can give new meaning to pedagogical practices [23]. The meaningful development of Embodied Artificial Intelligence (Embodied AI) in education requires addressing two fundamental and deeply interconnected dimensions. The first involves rethinking the role of pedagogical design by advancing towards open, dynamic and embodied approaches that incorporate GenAi not merely as a technical tool, but as an agent of co-creation in teaching and learning processes [40]. The second key dimension involves the creation of complex and evolving digital ecosystems capable of integrating AI technologies with electronics, sensors, robotics, and extended-reality environments.

The pedagogical redesign we call for should be situated in the realms of experience, the body, creativity, and emergence, moving away from the mere instrumentalization of teaching through technology [41], and fostering practices where the body and movement are fundamental

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[9] Peter Cariani. Design Strategies for Open-Ended Evolution. Artificial Life XI 2008 pp94-101

dimensions of knowledge. In this context, the increasing use of GenAi in educational settings is evident, ranging from the generation of text, images, and videos to the automation of evaluative processes and the methodological support provided by virtual tutors. The findings of Cosentino et al. [42] on the relationship between human teachers and GenAi systems in embodied mathematics learning underscore the need for a complementary interaction model, one that enriches various stages of the educational process by combining the immediacy of GenAi-generated feedback with the reflective and metacognitive guidance offered by human instructors. However, this integration is not without risks. One of the most prominent is the tendency to reproduce a "banking" pedagogy [2], in which both students and teachers are constrained by an algorithmic model that functions as an omniscient oracle. This logic reinforces dynamics of control, homogenization, and dependency, limiting the creative and critical potential of learning.

The instrumental logic of generative models, centered on prediction and control, tends to reduce the learner's agency and their ability to construct situated, affective, and embodied knowledge [43]. This reduction can lead to forms of the banality of evil, re-signifying Arendt's [44] notion in the context of contemporary education with AIgen, where students and teachers delegate their thinking and complex decisions to systems lacking ethics, historicity, and context. Arendt [44] coined the concept of the "banality of evil" to indicate that evil may arise not from deliberate malice, but from blind obedience, lack of judgment, and submission to impersonal systems. Thus, GenAi in education should not focus merely on producing efficient outputs, but rather on opening up spaces for dissonance, deliberation, and political imagination (see the work of Ai Weiwei, 2025).[10] Consequently, the challenge is not only technical but also enhances cultural diversity: to design technologies that do not repress cultural and sensory differences. Otherwise, we are facing a pedagogy in the form of "epistemicide" [45], which not only devalues embodied and ancestral knowledge but also depoliticizes education by undermining its practical and transformative potential.

In this scenario, the critical use of AI must be accompanied by formative processes that address its inner workings, its limits and its biases [46]. Dale Lane [47] argues that as long as teachers and students understand how to build neural network infrastructure at various scales, they will be better equipped to engage with the world, make informed decisions about usage, and choose what role they want AI to play in their future. As a result, they will develop stronger critical thinking skills and greater awareness of how AI can be used to find new and creative solutions to the problems that matter to them. We believe it is essential to reaffirm experience and learning-by-making through STEAM (science, technology, engineering, arts, and mathematics) tinkering practices to cultivate epistemic resilience, that is, resisting the temptation to outsource knowledge creation and embracing exploration, curiosity, creativity, and critical thinking. The ease of generating plausible arguments through LLMs-mediated dialogue may risk disintegrating the essential experience of effort and resistance, which is crucial for deep understanding.

To counter this inertia, pedagogical design must move beyond the canonical responses of the transmissive educational model and shift toward maker educational initiatives that promote the emergence of practical learning through STEAM projects that critically integrate the ethical

[10] Ai vs AI is a public artwork by Ai Weiwei that transforms interaction with artificial intelligence into a civic and aesthetic act. Presented over 81 days in cities like London and Berlin, the project juxtaposed philosophical questions answered by both the artist and an AI system, highlighting the role of AI in shaping meaning, memory, and freedom of expression in the digital age.

and aesthetic dimensions of AI, fostering creative, critical, and collaborative learning environments [48, 49]. Creativity, in this sense, is seen as an act of resistance against the mechanistic use of AI, allowing for a corporeal re-signification of the educational process. This also necessitates a critical revision of racial, social, and economic biases embedded in generative systems, whose symbolic architecture (the "generative homunculus") can perpetuate epistemic and cultural exclusion. Instead, we should aim to develop dynamic ecosystems of cognitive tools. Such ecosystems should be grounded in learning models that operate under conditions of uncertainty, improvisation, and dynamic coupling with changing contexts, abandoning the assumptions of stability and predictability that govern traditional teaching frameworks and by extension, AI with its LLMs. Furthermore, it is essential to critically challenge the epistemological foundations of mechanistic models that continue to promote a behaviorist view of learning as "reinforcement" or a cognitivist perspective based on "symbolic processing."

While notable advancements aim to transfer Embodied AI principles into education, such as the implementation of the humanoid robot NAO to support students with autism spectrum disorders, limitations persist. NAO's programming environment *choregraphe* [50], which relies on visual blocks and Python code, facilitates the creation of integrated multimodal behaviors (voice, vision, touch, movement), but still lacks flexibility in unpredictable scenarios. The system's ability to operate improvisationally or adaptively remains in its early stages, reflecting a structural gap in the development of open environments sensitive to situational emergence, as argued by Brooks [18] and Agre [51] and Dreyfus (1988) [52].[11] This implies reconfiguring not only technological infrastructures but also the theoretical frameworks guiding the design, mediation, and assessment of learning experiences. As suggested by the notion "If you can't dance your program, you can't write it," it is crucial to reframe movement as an integral part of educational design with AI [53].

Post-cognitivist perspectives enable a rethinking of Embodied AI design, both as a standalone approach and as part of integrated digital ecosystems, fostering more inclusive, adaptive, and creative learning environments. This approach redefines Human–Computer Interaction (HCI) by recognizing the body as a constitutive core of cognitive activity, challenging instrumental views that relegate the body to a secondary role. In this vein, we propose a set of pedagogical principles aimed at the critical and transformative integration of Embodied AI in contemporary educational contexts. These principles are methodologically grounded in Design-Based Research (DBR), which bridges theory and practice through a conception of learning as a dynamic, embodied, and affectively situated process [54].

Design Principles for Embodied AI in Education

(i) Overcoming Natural Language Models as Epistemic Centers

The pedagogical integration of AI demands the decentering of LLMs as the exclusive epistemic axis of intelligent educational technologies. While LLMs exhibit impressive linguistic capabilities, their logic based on the statistical prediction of language patterns, does not equate to situated understanding or meaningful pedagogical agency. Educational design should thus prioritize learning architectures that integrate the body, environment, and culture, recognizing that meaning emerges through interaction rather than through isolated linguistic representation.

[11] 'What computers can't do'. Later edition 'What computers still can't do'.

(ii) Situationality to Generate Meaningful Connections

Pedagogical design with Embodied AI should emphasize the co-creation of meaningful and context-sensitive relationships between bodies, artificial agents, environments, and knowledge domains. This involves moving beyond preprogrammed outputs to foster conditions in which relevant connections can emerge, informed by learners' histories, socio-material contexts, and affective engagements. From this perspective, AI is not merely a reactive system but an active participant in sense making and relational agency.

(iii) Distributed Creativity and Co-Agency

Pedagogical frameworks must support the emergence of distributed creativity, where innovation is not solely attributed to the human learner or the AI system, but co-constructed through open, interdisciplinary, and transductive flows of interaction. This approach challenges hierarchical distinctions between user and tool, promoting more participatory and horizontal configurations of agency.

(iv) Embracing Uncertainty, Failure, and Improvisation

In complex and dynamic educational environments, the capacity for adaptive response becomes essential. Both learners and AI systems must be allowed to explore, fail, adjust, and reconfigure their actions in real time. Avoiding rigid, overly deterministic instructional designs opens space for situated improvisation and epistemic risk-taking as legitimate forms of inquiry and growth.

(v) Critical Awareness of Bias and Algorithmic Performativity

Designing with AI requires a critical literacy around the performativity of algorithms, how they shape and reproduce specific ways of seeing, knowing, and acting. This principle entails an active interrogation of embedded biases, the conditions under which AI models are trained, and the broader socio-political consequences of their outputs, particularly in relation to epistemic exclusion and cultural homogenization.

(vi) Embodied Sensorimotor Multimodality

Truly embodied AI must integrate multimodal sensorimotor channels into the learning process, enabling educational experiences where vision, gesture, speech, movement, and touch are recognized as legitimate modalities of knowing and expressing. This principle is fundamental to inclusive pedagogies that honor the diverse cognitive and cultural ways of learning and inhabiting the world.

(vii) Ecological Design for Open Pedagogical Innovation

Educational spaces should be conceived as relational and evolving ecosystems, where AI is not imposed as a layer of control but becomes entangled within complex networks of bodies, materials, architectures, and discourses. This demands open, flexible, and adaptive infrastructures oriented toward the emergence of shared cognitive niches and sustained collective inquiry.

5. Conclusion

The recognition of embodied cognition as a constitutive foundation of knowledge provides a fertile framework for rethinking both computational development and educational design with AI. In this regard, Embodied AI, understood as an epistemological and pedagogical horizon, enables a reformulation of how we learn, teach, and engage with knowledge in technologically mediated contexts. However, its effective implementation requires material, institutional, and formative conditions that are often lacking in many educational settings, which could further exacerbate existing inequalities in access and participation.

From a critical and forward-looking perspective, we argue that Embodied AI can enable pedagogical pathways oriented toward inclusion, creativity, and contextualization, particularly when linked to open-source platforms that facilitate both an understanding of AI systems and the co-creation of automated tools. Along these lines, we propose strengthening interdisciplinary educational design through a STEAM approach by creating digital ecosystems that, within the framework of maker education, integrate artificial intelligence into multisensory and culturally meaningful experiences. This pedagogical orientation, centered on making, embodiment, and imagination, positions AI not as an end in itself but as a means to enhance agency, creativity, and situated understanding of the world.

Finally, we emphasize the urgency of reclaiming embodied and situated approaches that move beyond the instrumental and predictive models that currently dominate educational AI. Such a shift opens space for expanding the realm of the possible in aesthetic, epistemic, and formative terms. Only then will it be possible to conceive of learning experiences that are deeply sensitive, critical, and pluralistic, capable of resisting the homogenizing logic of automation and reconfiguring the role of technology in support of truly transformative education.

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