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AI Literacy and extended learning: toward an inclusive socio-technical pedagogy

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Abstract: Within networked learning ecosystems, AI Literacy becomes a fundamental condition for understanding how learning emerges from hybrid configurations of interaction among bodies, environments, and intelligent systems. This contribution conceptualizes cognition as an embodied, distributed, and co-evolutionary process and examines how the increasing presence of generative AI in everyday practices reorganizes attention, memory, participation, and autonomy. Far from being a mere digital support, artificial intelligence is interpreted as a socio-technical actor that co-shapes educational practices, languages, and meaning-making processes. This scenario reveals the limitations of both anti-smartphone rhetoric and transmissive instructional models, as they fail to account for the reality of extended and technologically mediated learning. Drawing on insights from special pedagogy and inclusive design, the paper argues that AI Literacy—understood as a critical, ethical, and operational capacity to engage with intelligent systems—can function as a facilitator for learners with diverse functioning profiles, enabling new forms of agency, regulation, and accessibility. The contribution aims to outline criteria for an extended pedagogy capable of integrating AI within the human–environment–technology network as a generative and inclusive component of contemporary cognitive ecosystems.

Keywords: AI Literacy; extended learning; socio-technical inclusion; educational agency

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1. Introduction

The rapid diffusion of networked technologies and artificial intelligence has profoundly transformed the conditions under which learning takes place. Educational processes are increasingly embedded within socio-technical ecosystems where cognition emerges from hybrid configurations involving bodies, environments, symbolic artifacts, and intelligent systems, rather than being confined within individual minds or isolated instructional settings (Latour, 2005; Rivoltella, 2017).

Within this scenario, traditional educational categories—such as attention, memory, participation, and autonomy—are not merely challenged, but progressively reconfigured. Attention is fragmented and redistributed across multiple interfaces; memory is increasingly externalized and delegated to digital systems; participation is mediated by platforms and algorithms; autonomy itself becomes relational and

technologically situated. These transformations demand renewed theoretical and pedagogical scrutiny capable of accounting for the material, relational, and technological dimensions of learning (Fabiano, 2021).

Educational debate often reacts to these changes through defensive narratives. Digital technologies—and especially smartphones and generative AI—are frequently framed as disruptive forces to be controlled, restricted, or excluded from school environments. In parallel, technosolutionist approaches promise efficiency, personalization, and optimization, often presenting technology as a neutral or benevolent enhancer of learning outcomes. Both perspectives, however, risk simplifying the complexity of contemporary educational environments and obscuring the deeper cultural and cognitive implications of technological mediation (Dipace et al., 2023).

What these opposing narratives share is a tendency to treat technology as something external to learning, either as a threat or as a solution. In reality, learning today is increasingly extended and distributed across human and non-human actors. It unfolds within environments shaped by platforms, interfaces, algorithms, and networked infrastructures that actively participate in orienting attention, shaping interaction, and mediating access to knowledge. Ignoring this structural embeddedness prevents education from addressing the actual conditions under which learning occurs (Latour, 2005).

This contribution situates itself within this tension and proposes a pedagogical reframing of AI Literacy as a central condition for understanding and inhabiting extended learning ecologies. Rather than treating artificial intelligence as a neutral digital support, the paper conceptualizes AI as a socio-technical actor that co-shapes educational practices, languages, and meaning-making processes. Such a perspective requires moving beyond transmissive models of instruction and purely regulatory responses, which prove inadequate in addressing the complexity and dynamism of contemporary learning environments (Dipace, Fornasari, & De Angelis, 2023).

Drawing on extended cognition, media education, and pedagogical reflection on inclusion and agency, the paper aims to delineate criteria for an extended pedagogy capable of integrating AI within the human–environment–technology network. In doing so, AI Literacy is reinterpreted as a critical, ethical, and operational capacity that supports regulation, participation, and accessibility, particularly in relation to learners with diverse functioning profiles (Rivoltella, 2017; Spadafora, 2019).

2. Extended Cognition and Socio-Technical Learning Ecologies

Understanding contemporary learning requires a decisive shift from individualistic and internalist models of cognition toward perspectives that emphasize distribution, embodiment, and co-evolution. Cognitive processes do not reside solely within the individual mind but emerge from continuous interactions among bodies, tools, environments, and social relations. Learning, therefore, cannot be fully understood without considering the material and relational contexts in which it takes place (Berthoz, 2015).

Within socio-technical learning ecologies, technologies are not external add-ons to cognition but constitutive elements of it. Writing systems, digital devices, interfaces, and algorithmic architectures actively participate in shaping perception, memory, and meaning-making. These artifacts reorganize cognitive effort, redistribute attentional resources, and create new temporalities of learning, reinforcing the distributed nature of cognition (Latour, 2005).

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Learning ecologies can thus be understood as dynamic systems in which knowledge emerges through participation, negotiation, and adaptation rather than linear transmission. From this perspective, cognition unfolds across heterogeneous components, intertwining human agency with material and technological mediation. Educational environments become assemblages in which learning is co-produced by subjects, artifacts, and institutional practices (Rivoltella, 2017).

The body plays a crucial role within these ecologies as a site of perception, action, and regulation. Learning is inseparable from bodily engagement, movement, and sensory experience. Attention, in particular, is shaped by environmental affordances and technological cues that orient perception and interaction, highlighting the embodied nature of cognitive processes.

Berthoz's concept of vicarianza provides a particularly useful interpretive lens for understanding these dynamics. Human cognition is characterized by the capacity to reorganize action and perception in response to environmental constraints, generating alternative pathways when direct solutions are unavailable. This adaptive flexibility underscores the relational and situated character of learning, emphasizing that cognition is always negotiated within concrete contexts (Berthoz, 2015).

Artificial intelligence intensifies these dynamics by introducing systems capable of responding, adapting, and generating content. Generative AI modifies the temporal and cognitive structures of learning by externalizing processes of recall, synthesis, and production. This externalization does not replace human cognition but reconfigures it, creating new forms of cognitive coupling that require careful pedagogical interpretation (UNESCO, 2023).

3. Artificial Intelligence as a Socio-Technical Actor in Education

In educational discourse, artificial intelligence is often described as a tool designed to assist teaching and learning. While this instrumental framing highlights practical applications, it fails to capture the deeper socio-technical role of AI within educational ecosystems and underestimates its capacity to shape educational practices and meanings (Fabiano, 2021).

Artificial intelligence systems—particularly generative models—do not merely execute predefined functions. They actively participate in shaping practices, languages, expectations, and evaluative criteria. Recommendation systems influence what learners encounter; adaptive platforms reorganize learning paths; generative tools reshape authorship and production. In doing so, AI contributes to redefining what counts as relevant knowledge and legitimate participation (UNESCO, 2023).

Conceptualizing AI as a socio-technical actor implies recognizing its capacity to influence educational interactions in non-neutral ways. Actor-network theory offers a useful framework for this analysis, as it conceives agency as distributed across networks of human and non-human actors rather than located exclusively within individuals. Within such networks, technologies acquire agency through the relations they establish with users, institutions, and cultural norms (Latour, 2005).

This reconfiguration challenges traditional pedagogical assumptions. Instructional models based on linear transmission of content or rigid curricular sequences struggle to account for learning processes that are increasingly nonlinear, multimodal, and mediated by intelligent systems. Similarly, regulatory responses focused on banning devices or restricting access fail to engage with the lived reality of learners, whose

cognitive and social practices are already deeply intertwined with digital environments (Rivoltella, 2017; Dipace et al., 2023).

From a critical pedagogical standpoint, the central issue is not whether AI should be present in education, but how its presence is interpreted and guided. Without pedagogical mediation, AI risks reinforcing passive consumption, delegating cognitive effort, and standardizing responses. When critically integrated, however, it may support metacognition, creative exploration, and differentiated access to learning opportunities.

4. AI Literacy, Inclusion, and Educational Agency

Within extended learning environments, AI Literacy emerges as a foundational educational construct. Rather than being limited to technical proficiency, AI Literacy encompasses the capacity to understand, critically evaluate, and ethically engage with intelligent systems. It involves awareness of how AI operates, how it shapes information flows, and how it affects autonomy, responsibility, and decision-making (UNESCO, 2023).

AI Literacy can be understood as a form of cultural competence that enables learners to navigate complex socio-technical environments. It includes the ability to question algorithmic outputs, recognize biases, and reflect on the implications of delegating cognitive tasks to automated systems. In this sense, AI Literacy supports reflective agency rather than mere functional adaptation (Rivoltella, 2017).

From the perspective of special pedagogy, AI Literacy acquires additional significance. Inclusive education requires attending to diverse functioning profiles and designing learning environments that support participation, regulation, and agency. AI-mediated tools may offer adaptive supports, multimodal access, and personalized scaffolding that enhance learning opportunities for students with disabilities or learning difficulties (Spadafora, 2019).

However, inclusion cannot be reduced to technological accommodation. Without critical AI Literacy, learners risk becoming dependent on automated supports without developing reflective control over their use. Pedagogical design must therefore balance assistance with empowerment, ensuring that AI functions as a mediator rather than a substitute for agency.

Spadafora's reflection on democratic education provides a normative horizon for this balance. Educational innovation must be guided by explicit pedagogical purposes oriented toward participation, agency, and social justice. Within this framework, AI Literacy becomes a condition for sustaining democratic educational practices in technologically saturated environments (Spadafora, 2017; Spadafora, 2019).

5. Discussion

The analysis developed throughout this paper suggests that contemporary educational challenges cannot be adequately addressed through defensive, normative, or purely instrumental approaches to technology. The growing pervasiveness of artificial intelligence within learning environments highlights the inadequacy of educational models that continue to interpret technological mediation either as an external disturbance or as a neutral support for instructional efficiency (Fabiano, 2021).

The emergence of extended learning ecologies calls for a reconfiguration of pedagogical categories, professional roles, and educational responsibilities. In such

ecologies, learning unfolds across heterogeneous networks of human and non-human actors, where technologies actively participate in shaping cognitive processes, interactional dynamics, and evaluative criteria. Ignoring this condition risks producing pedagogical responses that are misaligned with the lived experience of learners, whose cognitive practices are already deeply embedded in socio-technical environments (Latour, 2005).

Framing artificial intelligence as a socio-technical actor allows for a more nuanced interpretation of its educational implications. Rather than focusing on the presence or absence of AI in educational settings, this perspective foregrounds the quality of pedagogical mediation through which AI is integrated. Transmissive instructional models, which rely on linear content delivery and predefined learning paths, struggle to account for the nonlinearity, adaptivity, and generativity introduced by intelligent systems (Rivoltella, 2017).

Similarly, regulatory responses based on prohibition or restriction—such as blanket bans on devices or platforms—often fail to engage with the complexity of contemporary learning practices. Such measures may temporarily reduce visible forms of technological mediation, but they do not address the underlying cognitive and cultural transformations that characterize digital environments. In this sense, regulation without pedagogy risks becoming an empty gesture, disconnected from educational meaning-making processes (Dipace et al., 2023).

The discussion gains further relevance when considered from the perspective of inclusion. In extended learning ecologies, technological mediation may either expand or constrain participation depending on how it is pedagogically framed. Artificial intelligence can support accessibility, personalization, and multimodal engagement, particularly for learners with diverse functioning profiles. At the same time, uncritical adoption of AI-driven tools may reinforce dependency, obscure individual needs, or standardize learning experiences in ways that undermine agency (Spadafora, 2019).

An extended pedagogical approach requires holding together these tensions without resolving them prematurely. Rather than seeking definitive solutions, extended pedagogy emphasizes co-evolution, adaptation, and reflexivity. It recognizes uncertainty and complexity as intrinsic features of educational practice in technologically saturated contexts, resisting the temptation to reduce pedagogical decision-making to technical optimization or risk management (Berthoz, 2015).

Within this framework, AI Literacy emerges not merely as a set of competencies, but as a cultural and ethical orientation toward technology. It supports learners and educators in developing reflective awareness of how intelligent systems shape cognition, interaction, and responsibility. AI Literacy thus functions as a mediating construct that connects technological knowledge with pedagogical intentionality, enabling education to remain oriented toward agency and meaning rather than efficiency alone (UNESCO, 2023).

This perspective resonates with broader pedagogical reflections on democracy and education. As Spadafora has argued, educational innovation must be guided by explicit values and purposes that orient practice toward participation, responsibility, and social justice. In the absence of such orientation, technological innovation risks becoming detached from educational aims, reinforcing existing inequalities rather than addressing them (Spadafora, 2017; Spadafora, 2019).

Finally, extended pedagogy invites a rethinking of fear and resistance in relation to technological change. Rather than interpreting fear as an obstacle to innovation, it

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can be understood as an indicator of unresolved pedagogical questions. Resistance, in this sense, becomes a signal that calls for deeper reflection on the meanings, values, and assumptions underlying educational practices in socio-technical environments. This interpretive shift aligns with sociocultural critiques that highlight the ambivalence of modern technological transformations and the need for educational sense-making within conditions of uncertainty (Bauman, 2017).

6. Conclusions

This contribution has argued for a reconceptualization of AI Literacy within the framework of extended learning and inclusive socio-technical pedagogy. Artificial intelligence is not merely an external support to learning, but a generative component of contemporary cognitive ecosystems that actively participates in shaping educational experience (Latour, 2005).

By foregrounding embodiment, distribution, and agency, extended pedagogy offers criteria for designing learning environments that integrate AI as a meaningful and inclusive element of educational practice. In this perspective, learning is understood as a relational and situated process that unfolds across human and technological actors (Berthoz, 2015; Rivoltella, 2017).

AI Literacy becomes a facilitator of autonomy, regulation, and access rather than a purely technical skill set. It supports learners in navigating complex socio-technical environments responsibly and critically, preserving the ethical and democratic dimensions of education.

Future research and educational practice are called to further explore how extended learning ecologies can be designed to support diverse learners while sustaining agency, inclusion, and pedagogical responsibility in an age of artificial intelligence (UNESCO, 2023; Spadafora, 2019).

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