Journal of Inclusive Methodology and Technology in Learning and Teaching
ISSN 2785-5104
Anno 6 n. 1 (2026)

EDIZIONI UNIVERSITARIE ROMANE
editoria scientifica dal 1952

Beyond Nature Deficit Disorder: an ecology of learning that integrates nature, technologies and neuroeducation

Marianna Liparoti [1]

[1] University of study "G. d'Annunzio" Chieti-Pescara; marianna.liparoti@unich.it

Abstract: This paper explores the integration of outdoor education and artificial intelligence (AI) from a neuroeducational and synecological perspective, viewing learning as an embodied, relational and ecologically situated process. Starting from a contemporary critical issue such as *Nature Deficit Disorder*, the study analyses the educational potential of outdoor settings as privileged environments for the activation of cognitive, emotional and social processes, in which AI can be rethought as a mediating presence rather than a substitute for direct experience.

In this context, AI is problematized not as a substitute for direct experience, but as a mediating device capable of supporting personalisation, monitoring and metacognitive awareness, if it is inserted in contexts that preserve the centrality of the body, the educational relationship and the natural environment. Through a critical reinterpretation of the literature on outdoor education and AI-based technologies in education, this contribution proposes the concept of outdoor education as an "integrated neuroeducational laboratory", in which nature and intelligent technologies can coexist in a mutually reinforcing relationship.

The analysis highlights how the effectiveness of this integration depends on pedagogical intent, the critical skills of teachers and an ethical framework based on transparency, data awareness and ecological responsibility. What emerges is a vision of educational innovation geared not towards technocratic optimization, but towards the construction of complex educational ecosystems, in which embodied experience and digital mediation interact in a balanced and conscious manner.

Keywords: Outdoor education; Artificial Intelligence; Educational neurosciences.

1. Introduction

In recent decades, dialogue between neuroscience and educational science has made it increasingly clear that learning processes are rooted in embodied, multisensory, and relational experiences (Rivoltella, 2018). We learn through our bodies, emotions, and interactions with others, in a continuous intertwining of biological, social, and cultural dimensions.

Bronfenbrenner (1979), with his ecological model of human development, emphasized that growth occurs within interconnected systems, family, school, community, natural environment, that act synergistically, influencing each other and affecting overall development. Human development, therefore, is not a linear process, but a complex and constantly evolving path, the result of the interaction between individual characteristics and the surrounding environment. This perspective is confirmed by neuroscientific research (Mualem et al., 2024), showing that the brain is highly plastic and sensitive to the quality of environmental stimuli, which can leave a profound mark on the formation of neural connections and future cognitive, emotional, and social skills.

At the same time, pedagogy has always valued the experiential dimension of learning. Starting with Dewey (1986), who highlighted how doing and experiencing authentic situations form the basis for the construction of meaning, to Malaguzzi (1996), who reiterated how wonder, creativity, and play represent privileged languages through which to explore the world and construct knowledge. In this context, open spaces take on a strategic educational role as stimulating learning environments which, beyond neuro-mythical simplifications (Rivoltella, 2012), are capable of activating cognitive, physical, and symbolic processes. Farné (2018) defines this perspective as outdoor education, a pedagogical approach that values outdoor spaces not only as physical places, but as educational contexts capable of stimulating divergent thinking, autonomy, and cooperation: environments in which children and young people can experiment, make mistakes, plan, and collaborate in an active and participatory way.

However, the contemporary world is a complex and problematic scenario, in which the global ecological crisis, the intensification of urbanization processes, and the weakening of contact with nature are contributing to a profound redefinition of the conditions in which new generations are growing up (Mortari, 2020). Richard Louv (2005) coined the term *Nature Deficit Disorder* to describe children's progressive loss of contact with nature and the negative consequences this has on their mental and physical well-being, which risks compromising their overall development (Mueller, 2009). In Italy, the Ministry of Enterprise and Made in Italy found in 2024 that children and adolescents between the ages of 8 and 18 spend between one and three hours a day online, and about one in five exceeds four and a half hours of daily use of digital devices and content. Such an investment of time in the digital world has significant cognitive, emotional, and social implications (Kar et al., 2025). This period of systemic transformation also sees the emergence of Artificial Intelligence (AI), which is an emerging component of the socio-technological ecosystem within which the education of new generations is developing (Liparoti, 2024). If, as highlighted by ecological and neuroscientific perspectives, human development is the result of dynamic interactions between organism and environment, AI becomes part of that cultural and cognitive environment that shapes experiences, attention, modes of access to knowledge, and decision-making processes. The pedagogical question cannot therefore be limited to recording its spread but must ask how to critically guide its integration.

In this study, through a neuroeducational and synecological perspective, aim to outline how AI can be conceived as a mediation device capable of supporting reflective processes, personalization, and inclusion, if it is inserted in contexts that preserve the centrality of relationships, the body, and the natural environment.

2. Outdoor education as a pedagogical and ecological framework

Outdoor education, understood as a pedagogical and ecological framework, now has an increasingly solid theoretical and practical foundation, as it responds to a deep anthropological need that Edward O. Wilson (1984) defined with the term *biophilia*, i.e., the innate tendency of human beings to seek a connection with nature and other forms of life. This is not simply an aesthetic inclination, but a genuine existential orientation, rooted in the evolutionary history of the species, which recognizes the relationship with the natural environment as a necessary condition for physical, mental, and social well-being. Neglecting this predisposition can have significant consequences. The progressive reduction in the amount of time children spend in natural environments, while not a clinical condition, is a global phenomenon with important repercussions on well-being (Chawla, 2015; Gill, 2014).

In this context, outdoor education is a pedagogical and social response to an ecological and educational crisis, restoring nature's primary educational function. Its strength lies in integrating the human need for contact with the environment with the objectives of contemporary education: counteracting technological dependence and sedentary lifestyles, promoting integral development, strengthening cognitive and socio-emotional skills, and cultivating conscious ecological citizenship.

The roots of this approach lie in classical pedagogy. In *Emile*, Rousseau emphasizes the importance of physical space and the natural timescales of growth; Pestalozzi, in *Leonardo and Geltrude*, proposes an education that harmonizes head, heart, and hand, integrating intellectual and manual activities. Fröbel, Montessori, and the Agazzi sisters follow this line of thinking, conceiving the educational environment as a space intentionally designed to foster autonomy, creativity, and experiential learning.

This vision is not confined to pedagogical reflection but is explicitly recognized in national and international policy documents. The United Nations 2030 Agenda links quality education (Goal 4) to the protection of ecosystems (Goals 13, 14, 15), emphasizing the need to educate citizens who can understand the complexity of natural and social systems. Outdoor education embodies this perspective, promoting active and interdisciplinary learning that integrates scientific knowledge, ethics, and ecological citizenship. In Europe, the Council Recommendation on learning for environmental sustainability calls for the integration of practical and interdisciplinary experiences at all levels of education, valuing outdoor spaces as educational laboratories. Italy has adopted these guidelines: the Pedagogical Guidelines for the Integrated System 0-6 (Ministerial Decree 334/2021) recognize the strategic role of outdoor spaces for exploration, motor skills, and relationships; the National Curriculum Guidelines (2012) promote a workshop-based and interdisciplinary approach, in which nature becomes an authentic learning environment. These guidelines are in line with the UNESCO Roadmap 2030 for Education for Sustainable Development, which considers sustainability education to be a cross-cutting dimension of the curriculum throughout life.

In Europe, outdoor education developed from forest kindergartens that originated in Denmark in the second half of the 20th century, then spread to several countries and was systematized in the United Kingdom with Forest Schools, which have shown positive effects on autonomy, self-esteem, language, and cooperation (O'Brien & Murray, 2007). Pedagogical literature emphasizes that outdoor education is not a recreational activity, but a real teaching tool capable of broadening educational methodologies and promoting experiential and transdisciplinary learning (Waite & Pratt, 2011a).

From a strictly pedagogical and didactic point of view, nature must therefore be configured as an interdisciplinary environment par excellence, capable of making physical, biological, and chemical processes investigable in vivo; of offering contexts for measurement, estimation, proportion, and modeling; of stimulating practices of representation, narration, and argumentation; and of prompting ethical and civic reflections on the care of common goods. In this perspective, the natural context becomes both the content and method of learning, integrating action, perception, and conceptualization into authentic tasks, supporting epistemic curiosity, divergent thinking, cooperative social skills, and the ability to connect different types of knowledge (Farné, 2018).

However, the contemporary pedagogical challenge does not lie in unilaterally emphasizing one learning environment over another, but in knowing how to develop a continuum between the different educational contexts, both natural and AI-mediated, that inhabit the experience of the new generations. Pedagogy is therefore called upon to build bridges between natural spaces and digital environments so that they can coexist, and this becomes possible by orienting the integration of AI within a framework of values that preserves the centrality of relationships, embodied experience, and ecological responsibility.

3. Outdoor activities and Artificial Intelligence: towards an integrated neuroeducational laboratory

The outdoor environment could be considered an integrated neuroeducational laboratory, i.e., a privileged educational space in which physicality, relationships, and ecological awareness come together in a dialogue that is now further explored and enriched by AI mediation.

From this perspective, the outdoor space is not simply a physical context, but a dynamic environment in which perception, movement, emotion, and symbolic construction converge in the definition of situated and meaningful learning. Knowledge takes shape through direct experience: traversing a space, touching natural materials, listening to environmental sounds, and modulating the body in relation to the surrounding elements. These experiences contribute to the simultaneous activation of different sensory channels, which promote the consolidation of memory traces and lend stability and depth to the processes of understanding, rooting them in lived experience (Glenberg, 2010; Paloma, 2013; Shams & Seitz, 2008). Within this horizon, AI can be used as a pedagogical mediation device capable of amplifying, without replacing, the sensory density of the experience. Research on wearable technologies and adaptive systems shows that, when integrated in an intentional and educationally oriented way, they can support body awareness and situated exploration, offering contextual feedback that accompanies action without fragmenting it into decontextualized data (Lindberg et al., 2016; Molavian et al., 2023). At the same time, studies on intelligent systems in education highlight how AI can act as a training aid rather than a substitute for direct experience, provided that its function remains within a conscious pedagogical framework (Holstein et al., 2019; Roll & Wylie, 2016).

In this configuration, the outdoor environment retains its central role as the primary place of learning, while technology acts as a complementary and non-invasive element, capable of interacting with the complexity of the experience without reducing it. Digital innovation, understood in this way, does not diminish the perceptual, emotional, and relational quality of the context, but can contribute to making it more conscious and articulated, strengthening the intertwining of embodied experience and conceptual understanding. What emerges is a vision of the outdoors as a formative ecosystem in which nature and intelligent systems coexist in a mutually reinforcing relationship, preserving the centrality of the subject and the depth of the lived experience.

The outdoor environment is also a space of pedagogical balance between stability and openness, between reassuring structure and exploratory tension. In it, the presence of recognizable elements places students in a condition of reduced mental load, creating conditions of safety that are functional to learning (Diamond, 2013). Furthermore, the natural environment reduces stress and promotes positive emotional states (Park et al., 2010; Ulrich et al., 1991), creates conditions conducive to concentration and perseverance. At the same time, the external environment can become a field of investigation, stimulating executive functions such as planning, cognitive flexibility, inhibitory control, and problem solving. The experience thus takes the form of an open process, in which knowledge is constructed through interaction with the context, environmental stimuli, and interaction with peers. In this framework, AI can play a supporting role in the differentiation and personalization of learning paths, suggesting operational variations consistent with the students' level of competence or offering timely feedback that guides action without replacing it. However, the ultimate responsibility for constructing meaning remains with the teacher, the guardian of fairness, pedagogical consistency, and the ethical dimension of learning (Liparoti, 2024). In this sense, technology does not determine the direction of education, but accompanies it, remaining within the confines of intentional planning.

The outdoor environment encourages exploration through movement, a central element in cognitive and emotional development. The pedagogical value of *risky play* (Sandseter, 2009), understood as an experience of calibrated and intentionally mediated uncertainty, also fits into this perspective. Facing situations that are not completely predictable, such as climbing, crossing, orienting oneself, and cooperating in variable contexts, stimulates situational judgment, a sense of self-efficacy, and resilience. Risk thus becomes an educational opportunity, a space for exercising responsibility, assessing consequences, and regulating emotions. In this scenario, the integration of AI-based wearable technologies, if pedagogically oriented, can serve as a conscious guide to bodily experience. Devices capable of providing feedback on rhythm, posture, physiological parameters, or movement dynamics do not reduce action to quantification, but can promote greater awareness of the body in that situation. Studies on the use of wearable technologies in educational contexts show that, when integrated in a thoughtful way, they support self-regulation and attention to bodily signals, without fragmenting the unity of the experience (Molavian et al., 2023).

The outdoors promotes the development of language and critical thinking through dialogue and fieldwork, in which direct observation is intertwined with argumentation and the negotiation of meanings (Mercer & Littleton, 2007). In this context, the integration of Artificial Intelligence can become a privileged opportunity for digital and critical literacy, preventing forms of uncritical deference to automated systems. When the functioning of algorithms is made transparent and subject to discussion, interaction with AI helps to strengthen metacognitive awareness: comparing predictive outputs and data collected in the field, questioning the criteria used to construct models, and analyzing discrepancies between predictions and direct observation means educating people to use reflective judgment, not mechanical execution (Liparoti, 2024; Roll & Wylie, 2016). AI is thus taken as a situated and partial perspective, to be problematized and contextualized.

On an ethical level, the intertwining of direct experience and intelligent technologies can reinforce an education oriented toward care and ecological responsibility. Shared maintenance activities or environmental monitoring encourage empathy, cooperation, and a sense of belonging (Decety & Cowell, 2014; Eisenberg et al., 1983), while teacher mediation ensures that data collection and use are carried out with transparency, informed consent, and minimization.

Assessment can also benefit from a balanced integration of pedagogical documentation in outdoor environments and digital tools: experiential portfolios, observation rubrics, and narrative maps of progress can be enriched by data collected in outdoor environments through AI, offering a more articulated view of learning processes. However, the measurable dimension does not exhaust the complexity of education: the teacher's professional judgment remains decisive in grasping the relational, symbolic, and transformative qualities of the experience (Wiggins, 1998).

4. Pedagogical implications of integrating outdoor education and artificial intelligence

In the context of the transformations that are taking place in contemporary society, the integration of outdoor education, neuroeducation and AI calls for reflection that cannot be reduced to either technophile enthusiasm or conservative mistrust. Rather, it challenges the pedagogical responsibility to rethink learning contexts as complex ecosystems in which the body, environment, relationships and technology co-participate in the construction of knowledge. From this perspective, AI is not added to the educational experience from outside, but is integrated into a fabric already dense with sensory, emotional and symbolic interactions, which find a privileged matrix in the outdoor space (Waite & Pratt, 2011b).

The outdoor environment, taken as a neuroeducational laboratory, makes the embodied nature of learning visible: knowledge takes shape in situated action, emotional regulation, and intersubjective negotiation. Inserting AI into this horizon therefore means questioning its role not as an agent of optimization, but as a device capable of dialoguing with such complexity. When pedagogically oriented, technology can offer additional levels of interpretation of the processes at work, patterns of participation, collaborative dynamics, environmental indicators, and performance indicators, without claiming to exhaust their meaning (Roll & Wylie, 2016).

Within this framework, the role of the teacher remains decisive. The literature highlights how the effectiveness of AI-mediated education depends less on the degree of sophistication of the tools and more on the quality of the pedagogical intent that guides their use. In an outdoor environment, where learning is rooted in multisensory experience and interaction with the context, teachers are called upon to maintain continuity between experience and reflection, preventing algorithmic data from overlapping with lived observation. This requires not only technical skills, but also a solid critical literacy in AI (Selwyn, 2019): ability to question the operating criteria of systems, recognize their biases, and contextualize their outputs within ethical and cultural framework. The act of education thus takes the form of conscious mediation between embodied experience and digital representation.

This approach challenges dominant narratives based on efficiency, standardization, and control (Biesta, 2012). Outdoor education, integrated with AI, can instead enhance slowness, exploration, and complexity, restoring centrality to physicality and the emotional dimension as generative conditions of knowledge. AI does not take on the role of a substitute, but rather that of a reflective mediator, capable of amplifying awareness, inclusion, and ecological responsibility when incorporated into an explicit pedagogical project.

The adoption of AI in outdoor educational contexts requires, however, cultural vigilance and regulations(Selwyn, 2019). Smart technologies are not neutral: they incorporate classification logic, value hierarchies, and data selection criteria. In synecological contexts, it is essential to protect the ecological integrity of places, personal data, and the professional autonomy of teachers. This implies policies of data minimization, transparency in algorithmic decision-making processes, and the participation of educational communities in the choice and design of tools.

5. Conclusions

The intertwining of outdoor education, neuroeducation, and artificial intelligence calls for a profound redefinition of contemporary learning contexts. If human development is the result of dynamic interactions between organism and environment, then intelligent technologies also become part of the educational ecosystem, helping to shape practices, attention, and decision-making processes. However, their introduction cannot be interpreted in deterministic terms or reduced to a logic of efficiency.

The outdoor environment, taken as an integrated neuroeducational laboratory, highlights the embodied, multisensory, and relational nature of learning. In it, knowledge emerges from situated experience, exploration, movement, and dialogue. AI, within this framework, can perform a reflective mediation function, supporting processes of personalization, documentation, and metacognitive awareness, without replacing the perceptual and emotional density of lived experience.

The essential condition for this integration to be pedagogically meaningful lies in the intentionality of the project and the critical competence of teachers. It is educational mediation that ensures that algorithmic data does not prevail over professional observation, that measurement does not reduce the complexity of experience, and that technological innovation remains oriented toward inclusive and emancipatory ends.

In this perspective, education is not called upon to choose between nature and technology, but to build continuity between different environments, developing an educational ecosystem capable of combining physicality, relationships, and ecological responsibility with digital literacy and critical awareness. Outdoor education, integrated with an ethically and pedagogically oriented use of AI, can thus contribute to the formation of individuals capable of navigating contemporary complexity with discernment, care, and a sense of responsibility towards themselves, others, and the environment.

References

Biesta, G. (2012). Good education in an age of measurement. *Cadernos de Pesquisa*, *42*, 808–825.

Bronfenbrenner, U. (1979). The ecology of human development: Experiments by nature and design. Harvard University Press.

Chawla, L. (2015). Benefits of nature contact for children. *Journal of planning literature*, *30*(4), 433–452.

Decety, J., & Cowell, J. M. (2014). The complex relation between morality and empathy. *Trends in cognitive sciences*, *18*(7), 337–339.

Dewey, J. (1986). Experience and education. Taylor & Francis.

Diamond, A. (2013). Executive functions. *Annual review of psychology*, *64*(1), 135–168.

Eisenberg, N., Lennon, R., & Roth, K. (1983). Prosocial development: A longitudinal study. *Developmental Psychology*, *19*(6), 846.

Farné, R. (2018). Outdoor Education come orientamento per una pedagogia sostenibile. *STUDI SUPERIORI (ROMA-CAROCCI)*, 25–44.

Gill, T. (2014). The benefits of children's engagement with nature: A systematic literature review. *Children Youth and Environments*, *24*(2), 10–34.

Glenberg, A. M. (2010). Embodiment as a unifying perspective for psychology. *Wiley interdisciplinary reviews: Cognitive science*, *1*(4), 586–596.

Holstein, K., McLaren, B. M., & Aleven, V. (2019). Co-designing a real-time classroom orchestration tool to support teacher-AI complementarity. *Grantee Submission*.

Kar, S. S., Dube, R., Goud, B. K. M., Gibrata, Q. S., El-Balbissi, A. A., Al Salim, T. A., & Fatayerji, R. N. M. A. K. (2025). Impact of screen time on development of children. *Children*, *12*(10), 1297.

Lindberg, R., Seo, J., & Laine, T. H. (2016). Enhancing physical education with exergames and wearable technology. *IEEE transactions on learning technologies*, *9*(4), 328–341.

Liparoti, M. (2024). Digital education: Artificial intelligence and new frontiers for learning. *ITALIAN JOURNAL OF HEALTH EDUCATION, SPORT AND INCLUSIVE DIDACTICS*, *8*(3).

Malaguzzi, L. (1996). The hundred languages of children: The Reggio Emilia approach to early childhood education (a cura di C. Edwards, L. Gandini & G. Forman). Norwood, NJ: Ablex Publishing.

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: A sociocultural approach*. Routledge.

Molavian, R., Fatahi, A., Abbasi, H., & Khezri, D. (2023). Artificial intelligence approach in biomechanics of gait and sport: A systematic literature review. *Journal of Biomedical Physics & Engineering*, *13*(5), 383.

Mortari, L. (2020). *Educazione ecologica*. Gius. Laterza & Figli Spa.

Mualem, R., Morales-Quezada, L., Farraj, R. H., Shance, S., Bernshtein, D. H., Cohen, S., Mualem, L., Salem, N., Yehuda, R. R., & Zbedat, Y. (2024). Econeurobiology and brain development in children: Key factors affecting development, behavioral outcomes, and school interventions. *Frontiers in Public Health*, *12*, 1376075.

Mueller, M. P. (2009). Educational reflections on the "ecological crisis": Ecojustice, environmentalism, and sustainability. *Science & education*, *18*(8), 1031–1056.

O'Brien, L., & Murray, R. (2007). Forest School and its impacts on young children: Case studies in Britain. *Urban Forestry & Urban Greening*, *6*(4), 249–265.

Paloma, F. G. (2013). *Embodied cognitive science: Atti incarnati della didattica* (Vol. 1). Edizioni Nuova Cultura.

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., & Miyazaki, Y. (2010). The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental health and preventive medicine*, *15*(1), 18–26.

Rivoltella, P. (2018). La didattica come scienza bioeducativa. Questioni epistemologiche, prospettive di ricerca. *Research Trends in Humanities Education & Philosophy*, *5*, 22–28.

Rivoltella, P. C. (2012). *Neurodidattica. Insegnare al cervello che apprende*. Raffaello Cortina.

Roll, I., & Wylie, R. (2016). Evolution and revolution in artificial intelligence in education. *International journal of artificial intelligence in education*, *26*(2), 582–599.

Sandseter, E. B. H. (2009). Characteristics of risky play. *Journal of Adventure Education & Outdoor Learning*, *9*(1), 3–21.

Selwyn, N. (2019). *Should robots replace teachers?: AI and the future of education*. John Wiley & Sons.

Shams, L., & Seitz, A. R. (2008). Benefits of multisensory learning. *Trends in cognitive sciences*, *12*(11), 411–417.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of environmental psychology*, *11*(3), 201–230.

Waite, S., & Pratt, N. (2011a). Theoretical perspectives on learning outside the classroom: Relationships between learning and place. *Children learning outside the classroom from birth to eleven*, 1–18.

Waite, S., & Pratt, N. (2011b). Theoretical perspectives on learning outside the classroom: Relationships between learning and place. *Children learning outside the classroom from birth to eleven*, 1–18.

Wiggins, G. (1998). *Educative Assessment. Designing Assessments To Inform and Improve Student Performance.* ERIC.