MIRROR NEURONS AND ARTIFICIAL INTELLIGENCE: EDUCATIONAL PATHWAYS FOR SOCIO-EMOTIONAL INCLUSION IN TECHNOLOGY-MEDIATED LEARNING ENVIRONMENTS

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ABSTRACT

Artificial neural networks and mirror neurons represent distinct yet closely interconnected fields, with significant implications for the application of Artificial Intelligence to neurodevelopmental disorders, particularly Autism Spectrum Disorder. This paper explores their relationship by focusing on the role of the mirror system in imitation, emotional regulation, and the development of intersubjectivity. It also examines the use of social robots and augmented reality as technology-mediated experiences that may support these processes in children with ASD, fostering empathy and relational skills. Artificial Intelligence and Affective Computing are discussed as promising approaches for enhancing educational technologies through the integration of cognitive and emotional dimensions. Within this framework, the learning environment itself emerges as an active context of educational mediation, in which space, technology, and interaction jointly contribute to the construction of meaningful experience.

KEYWORDS

Mirror neurons; Artificial Intelligence; Socio-emotional inclusion.

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1. Introduction

This contribution develops a theoretical framework, supported by a targeted scoping review, connecting the mirror neuron system to the application of artificial intelligence, Affective Computing, and social robotics within inclusive learning environments. The analysis focuses on recent scientific literature and specifically addresses the issue, which is central and remains empirically unresolved, of transferring socio-emotional skills acquired in technologically mediated environments to natural contexts of interaction. The objective is to construct a theoretical framework that interprets educational technologies as tools of pedagogical mediation, whose effectiveness depends on the quality of the relational, didactic, environmental, and systemic conditions that enable the transfer of skills from interaction with the device to authentic participation in social life.

2. Neurobiological Foundations of Intersubjectivity: The Mirror System between Emotion, Relation, and Learning

The capacity to engage with the experience of others represents one of the distinctive traits of human cognition. Research indicates that this capacity is supported by specific neural structures, whose discovery has profoundly redrawn the boundaries between neuroscience, developmental psychology, and pedagogy. The mirror neuron system, identified in the premotor areas of the cortex, including Broca's area, can be understood as one of the neural systems that support intersubjectivity, contributing to the activation of intersubjective relations that underpin cognitive development and the social bonds forming the basis of community (Rizzolatti & Gnoli, 2018). From this

perspective, understanding the other can be described as relying, at least in part, on a shared mechanism that unites the agent and the observer, alongside inferential and cultural processes.

Within psychoanalytic theories of early development, Winnicott (1974) had already highlighted the importance of the specular dimension in the emergence of the self. In his account of the mirror-role of the mother, the mother's face functions as an early form of mirror through which the child encounters a reflection of their own experience. The primary mother–child relationship thus becomes a relational space in which the emerging sense of self is progressively shaped through reciprocal interaction.

Gallese's (2008) identification of the concept of social identity, within the field of neuroscience, completes this framework by suggesting that the recognition of the other as a peer also rests on neural dispositions, which interact with cultural processes. The core of the mirror mechanism lies in its ability to unify perception and action within the same neural substrate.

As Rizzolatti and Sinigaglia (2006) note, observed and executed actions share the same neural code, and this coincidence is considered to support imitation and, consequently, learning. Mirror resonance alone, however, does not fully account for imitation and learning: area 46 of the prefrontal cortex, the locus of working memory, and the combinatorial systems responsible for creating new motor schemas integrate and complete what mirror resonance alone cannot ensure. Empathy represents the most complex and pedagogically relevant dimension of the mirror mechanism. The insula, a cortical region present in both hemispheres, encodes information regarding the emotional expressions of others, triggering a mirror mechanism capable of translating the visual signals of the observed emotion into analogous neuronal areas. Gallese (2008) terms this process *embodied simulation*: it does not entail imitation, but

rather the shared activation of neural repertoires, and it is precisely this sharing that enables the empathic understanding of the other. Within this framework, the imitative process emerges as a social operation wherein, without an understanding of the other's actions, no lasting bond would be possible for the human species (Rizzolatti & Gnoli, 2018).

3. Comparing Neural Architectures: Biological and Artificial Networks between Learning and Educational Mediation

The growing convergence between neuroscience and artificial intelligence has renewed scholarly debate on the question of how far contemporary computational architectures can be considered analogous to the functioning mechanisms of the human brain. Artificial Neural Networks (ANNs) are systems organized in layers of interconnected units, analogous to the networks of neurons present in the brain, capable of learning from data and generalizing responses based on training experience (Amatori & Pavone Salafia, 2026). Spiking Neural Networks (SNNs), the most promising frontier of neuro-inspired artificial intelligence, introduce a temporal dimension into signal processing that moves even closer to the behavior of real neurons. At a functional level, a parallel can be drawn between the mirror system, which responds to the observation of others' actions, and artificial networks, which operate through the shared activation of patterns learned from data. This parallel, however, is advanced here as a heuristic analogy rather than as a structural or biological homology: biological and artificial networks differ fundamentally in material substrate, developmental history, and embodiment.

The pedagogical interest of these architectures lies, beyond their computational capacity, in the possibility of modeling learning processes that recall certain aspects of human cognition. Indeed, neuroscience has shown how

learning emerges from the interaction among perception, action, emotion, and social context. Analogously, the new generations of intelligent systems are progressively integrating multimodal processing methods that combine language, images, gestures, facial expressions, and contextual signals.

From a pedagogical perspective, it is essential to distinguish three types of robotic application in the school setting: Assistive Robotics, which supports students with disabilities in classroom activities; Socially Assistive Robotics (SAR), oriented toward promoting the development of social skills; and Educational Robotics (ER), in which students themselves design and program robots, thereby developing transversal skills in problem-solving and collaboration.

Research from the MIT Media Lab (Kory Westlund et al., 2017) has documented how children learn new vocabulary from a robotic tutor using the same social strategies, shared gaze, body orientation, joint attention, that they employ with human interlocutors – an observation that may be read, at a heuristic level, as suggesting that children's social responses to a robot can parallel those elicited in human interaction.

The systematic review conducted by Salma et al. (2025), which analyzed 71 studies published between 2018 and 2025, highlights how the effectiveness of social robots depends on three design variables: anthropomorphism (humanoid systems such as NAO and Kaspar elicit significantly richer social responses), multimodal sensory capabilities (the combination of facial recognition, speech analysis, and tactile feedback maximizes interactive responsiveness), and the capacity for emotional expression (robots endowed with emotional expressiveness foster affective bonds that translate into greater engagement and improved learning outcomes).

With the evolution of machine learning, ANNs have acquired an exponentially greater predictive capacity in the simulation of complex behaviors. However, translating this computational power into effective educational applications requires preliminary pedagogical reflection: it is not enough for a robot to learn from behavioral data to become an effective educational mediator. The quality of the interaction depends on the coherence between pedagogical aims, the design of the artificial system, and the relational context in which it is embedded.

4. Cognitive profiles in ASD and the mirror system: from neuropsychological understanding to intervention technologies

Understanding the neuropsychological foundations of Autism Spectrum Disorder (ASD) is a preliminary condition for designing effective educational interventions. Despite the significant variability in individual profiles, individuals with ASD share impairments across three domains: reciprocal social interaction, verbal and non-verbal communication; as well as the presence of restricted and repetitive behavioral patterns. Neuroscientific research has progressively identified the mirror system as one of the biological substrates potentially involved in these difficulties. The broken mirror hypothesis, synthesized by Ramachandran and Oberman (2006), proposes that dysfunction of the mirror neuron system may contribute to difficulties in imitation, empathy, and interpreting others' intentions in ASD. Subsequent research, however, has provided mixed results and insufficient support for the hypothesis in its original, unitary form. Hamilton (2013), in a systematic review of 25 neuroscientific studies, concludes that the available data are overall mixed and lack unequivocal evidence of mirror impairment, proposing to move beyond the hypofunction model in favor of approaches that consider the top-

down modulation of mirror systems as a critical factor. A meta-analysis of fMRI studies (Chan & Han, 2020) documented not a hypoactivation but a hyperactivation of specific mirror areas in ASD during the observation of biological movements, with patterns modulated by the nature of the stimuli and the age of the participants, a result that could explain the contradictory data of previous research. Functional imaging studies have furthermore highlighted an atypical activation of the fusiform gyrus and a reduced activity of the amygdala, with consequences predominantly for the recognition of complex emotions, which require more refined cognitive processing compared to primary emotions (Gallese et al., 2009). From a pedagogical perspective, this controversy leaves the relevance of the mirror system open to investigation and requires caution in attributing social and imitative difficulties to a single neurobiological cause. The educational implications remain valid insofar as they are founded on the behavioral evidence of difficulties in imitation and emotional recognition, regardless of their precise neural origin (Cottini et al., 2023).

The concept of *vitality form* elaborated by Stern (2010) introduces a particularly significant dimension of analysis. Vitality forms concern the manner in which actions are executed (the rhythm, the intensity, the dynamic form of the movement), as distinct from their content and the underlying emotions, and allow the observer to infer the internal state of the agent. Unlike basic emotions, *vitality forms* modulate behavior in a continuous and nuanced manner, constituting the subtle fabric of prelinguistic communication. Neuroscientific research (Di Cesare et al., 2014) has identified the neural substrate of this mechanism in the insula, demonstrating that the perception of vitality forms is also involved in the mirror system. On a behavioral level, *eye tracking* methodology has made it possible to document how the time

dedicated to the observation of others' actions is roughly halved in children with ASD compared to typically developing peers (Cottini et al., 2023), with direct consequences on the effectiveness of imitative processes.

It has been observed that children with autism tend to emulate rather than imitate, more easily adopting gestures proposed by a mechanical arm compared to those of a human being (Gallese et al., 2009). It is therefore necessary to construct educational strategies that specifically support imitation, creating the conditions for interactive experiences in a context that offers safety in which to engage in repeated practice for the development of skills that are subsequently transferable to everyday experiences (Rossi, 2013). For this purpose, augmented reality (AR) allows for the creation of customizable environments adaptable to the characteristics of individuals with autism, offering contextual supports indications regarding behavioral rules, visual cues for understanding the emotions of others dedicated to supporting individuals' autonomy through a mixed system of anticipation and familiarization with individual tasks.

A strong synergy emerges between AR and artificial intelligence, aimed at creating immersive and interactive learning experiences that make the implicit elements, typical of social interaction, more explicit. The aim is not to "correct" but rather to create conditions that facilitate access to relational information and reduce the required cognitive and socio-emotional load.

5. Method: a targeted scoping review

To ground the theoretical framework empirically and to make its claims about the literature verifiable, a scoping review was conducted following Arksey and O'Malley (2005), as refined by Levac et al. (2010), with reporting aligned to the PRISMA-ScR checklist (Tricco et al., 2018). Eligibility was structured according

to the Population–Concept–Context (PCC) framework recommended by the JBI (Peters et al., 2020). Consistent with the nature of scoping reviews, no formal risk-of-bias assessment was performed (Munn et al., 2018). The review question was: to what extent do interventions based on advanced educational technologies (social robots, augmented reality, Affective Computing) promote the transfer of socio-emotional competences to non-mediated human interaction in children and adolescents with ASD?

The search was run on Scopus, chosen for its multidisciplinary coverage of education, psychology, cognitive neuroscience and computer science, and was last run on 30 June 2026. Two boundaries were deliberately and transparently adopted, defining the study as an exploratory, preliminary mapping: a single database and open-access records only. The latter ensures full accessibility and reproducibility of the full-text analysis, while introducing a selection bias explicitly acknowledged among the limitations. The search combined four blocks (ASD; advanced technologies; socio-emotional competences; transfer/generalisation), restricted to 2015–2026, document types 'article' and 'review', and English or Italian language.

Inclusion criteria were: children/adolescents with ASD (0–18 years); an intervention or synthesis involving social robots, AR/VR/MR, Affective Computing or affect-oriented serious games; at least one socio-emotional outcome (emotion recognition, empathy, theory of mind, social interaction, emotional regulation); empirical studies or reviews with an empirical basis. Records were excluded when out of the age range or without an ASD focus (E1), when the technology was not pertinent or absent, as in purely correlational studies (E2), when no socio-emotional outcome was measured, as in diagnostic or computer-vision studies (E3), for non-pertinent document types (E4), language (E5) or time window (E6), or when the full text was not retrievable

(E7) or not open access (E8). Screening and charting were performed by the first reviewer using a piloted grid; a second reviewer independently re-screened a random subset of the records to check consistency, and any discrepancies were discussed and resolved by consensus (this is acknowledged among the limitations). The grid recorded bibliographic data, sample, technology, outcomes, transfer, theoretical framework and reviewer notes

6. Results of the scoping review

The search returned 117 records. Applying the open-access boundary removed 45 non-open-access records (E8), leaving 72 records for screening. Of these, 26 were excluded with reason – 14 for population outside the age range (E1), seven for the absence of a measurable socio-emotional outcome (E3), and five for non-pertinent technology (E2). A further 13 records could not be classified with certainty at title/abstract level – mainly mixed adolescent/adult samples or borderline document types (viewpoints and purely methodological papers) – and, given the exploratory and bounded design of the review, were not carried forward to the analysed corpus. Thirty-three studies were therefore included: 21 empirical studies and 12 reviews or meta-analyses. This funnel is the basis for the descriptive claims that follow, which are therefore documented rather than assumed.

With respect to technology, virtual reality dominates the corpus (13 of 33 studies), followed by social robots (10) and Affective Computing (6); augmented reality is used in two studies; the remaining two included studies are reviews not attributable to a single primary technology, so that the four primary-technology categories account for 31 of the 33 included studies. The field is expanding rapidly: studies published in 2025–2026 account for 52% of the included corpus. From a demographic standpoint, the examined studies are

conducted predominantly on school-aged children (4–12 years), with a marked underrepresentation of preschool and adolescent groups, and most feature small samples (frequently fewer than twenty participants); transfer, where addressed, is examined predominantly in clinical and rehabilitative settings rather than in ordinary educational contexts. A further descriptive finding concerns the disciplinary provenance of the studies: only eight of the 33 originate from departments of education or pedagogy, the field being led instead by computer science and robotics, medicine and rehabilitation, and psychology; notably, none of the six studies with Italian lead affiliations originates from a pedagogy department.

Two thematic results are central to the review question. First, transfer is the most persistent and least addressed issue of the field: several syntheses converge in noting that interventions improve competences within the mediated environment but rarely verify whether these persist in the classroom, in free play, with peers or in the family. Among the studies that measure it, transfer often fails when it is not deliberately designed, whereas studies that build the intervention around ecologically pertinent scenarios and explicit bridging strategies report better generalisation; across the corpus, the recurring condition of success is the presence of a qualified human mediator, so that technology never proves effective in isolation. Second, the mirror neuron system does not appear among the author keywords of any of the 117 retrieved records; since the search string did not include mirror-neuron terms, this finding is only indicative, but it suggests that the framework linking the mirror system, imitation and socio-emotional transfer has not yet been made explicit in this body of research

7. Affective Computing, artificial intelligence, and social robotics: new frontiers for socio-emotional development

If the mirror system is involved in emotional attunement, the question guiding this section is whether, and to what extent, such attunement can be reproduced or supported by artificial systems. The most comprehensive answer is offered by Affective Computing, a term coined in 1995 by Rosalind Picard of MIT, which designates the design of computational systems capable of recognizing, interpreting, and responding to users' emotional states (Poria et al., 2017). The connection with the mirror system is profound: while mirror neurons are associated with emotional attunement between individuals, Emotion AI systems aim to artificially support a comparable attunement in contexts where it is compromised.

The systematic review by Salma et al. (2025) documents how robots such as Kaspar, designed for children with social communication disorders, operate through an intentional simplification of facial expressions and a reduction in the ambiguity of social cues, creating a simplified mirror context: an interactive environment in which the perceptual complexity of human interaction is reduced to discrete and coded signals, which may be more accessible to children who show documented difficulties in imitation and emotion recognition (see Section 4).

Ahmad et al. (2019) demonstrated, in a longitudinal study of primary school children, that positive emotional feedback provided by the NAO robot during vocabulary learning activities resulted in significantly greater consolidation compared to negative ($p = 0.016$) and neutral ($p = 0.039$) feedback: a robot capable of building a memory of the user's emotional events achieves better results in terms of both social engagement and lexical consolidation.

Faria et al. (2025) developed a multimodal real-time emotional recognition system applied to the NAO robot in a child-robot interaction context with fourteen children aged five to eight years (a pilot study with a small sample, the results of which should be considered exploratory). When a negative emotional state was dominant for over a minute, the robot activated emotional regulation strategies (music, dance), documenting a transition toward neutral or positive states. The longitudinal analysis of the interaction phases documented a progressive reduction in anxiety and an increase in happiness, with more pronounced effects in the phases of greater reciprocity (imitation, dance).

From a pedagogical perspective, these exploratory data offer a preliminary illustration of the hypothesis that Affective Computing systems capable of detecting and responding to emotional states in real time may perform an emotional scaffolding function, activating dynamics that can be read, heuristically, as parallel to those associated with the mirror system, in which the responsive contingency of the robot may approximate the affective attunement that Stern (2010) describes as a basis of primary intersubjectivity. In this regard, David and David (2022) documented how a robotic agent performs a cognitive-affective scaffolding function in sixty children aged 9-10 years with performance anxiety, demonstrating superior results compared to control conditions based on cartoons or written text. However, the evidence also reveals current limitations: the ability to maintain engagement over time and the significant individual differences in response profiles (Rudovic et al., 2018).

The most fruitful perspective is to employ AI systems as amplifiers of educational capacity, without replacing the human relationship, tools that provide the teacher with systematic information regarding the student's behavior, emotions, and engagement, thereby enabling more calibrated and personalized interventions.

8. Learning environment and transfer of socio-emotional skills: toward a Digital Affective Literacy

Within the reflection on educational technologies for ASD, the issue of transfer represents one of the most relevant and least explored theoretical and empirical issues. Transfer can be understood as the process through which a socio-emotional skill, acquired in a technologically mediated environment, is capable of being subsequently mobilized in different contexts, with different interlocutors, and in progressively less structured situations. Generalization is its observable manifestation: the ability to stabilize and reuse the skill as settings, interlocutors, times, and interactive demands vary. This distinction is particularly relevant in ASD, as it allows for the avoidance of an improper conflation of the child's adequate response to the technological device and the actual acquisition of a social skill that can be utilized in daily life.

Recent studies indicate that generalization does not depend solely on the quality of the technological intervention but on the configuration of the environment in which it is embedded: the environmental arrangement, the intentional structuring of spaces, materials, and routines, constitutes one of the necessary conditions to facilitate the transition of acquired skills toward natural contexts of interaction (Raulston & Hansen, 2021).

This perspective problematizes an implicit assumption recurrent in the literature: that the acquisition of a skill in a technologically mediated

environment constitutes in itself a sufficient, or at least preliminary, condition for subsequent generalization. Vivanet (2015) already identified the verification of generalization to daily life environments as one of the priority objectives for future experimentation with individuals with ASD; over a decade later, this critical issue remains largely unresolved. Pennazio (2019), in a critical review of thirty-five studies on the use of robotics for the development of social skills in children with ASD, highlights how research specifically oriented toward measuring transferability from the mediated environment to human interlocutors is scarce compared to the overall output, and proposes a validity distinction between in-environment outcomes, which are necessary to evaluate the proximal effectiveness of the intervention, and ecological outcomes, which are indispensable for affirming its inclusive value.

A useful analytical distinction identifies three levels of transfer. The first, proximal, concerns the observable response during interaction with the device. The second, near, refers to the reuse of the skill in guided activities with an adult or a mediated peer. The third, far, concerns generalization in natural and unstructured contexts: the classroom, the peer group, free play, the family, and extracurricular environments. Many studies focus predominantly on the first level, whereas research capable of documenting the transition to subsequent levels through naturalistic observations, longitudinal follow-ups, teacher and caregiver reports, and measures collected in non-experimental settings remains even less frequent.

At the international level, Esteban et al. (2017) and Kumazaki et al. (2017) posit generalization as the ultimate goal of Robot-Enhanced Therapy; Short et al. (2017), however, demonstrate that communicative behaviors elicited by human-robot interaction do not equate to proof of generalization in daily life. In most cases, transfer remains a stated objective that has yet to be

demonstrated. Vivanet (2015) reports that longer technological interventions prove less effective in the absence of specialist supervision, a finding which suggests that the decisive variable is less the time of exposure to the device than the quality of the pedagogical mediation that accompanies it.

Zappalà (2021) shifts the analysis from the measurement of outcomes to the design of conditions: educational continuity across formal, non-formal, and informal contexts cannot be guaranteed by episodic technological interventions, regardless of their methodological rigor. The study by Vona et al. (2025) on technology-assisted ABA interventions is consistent with this interpretation, making visible a multilevel chain of mediations, technology, practitioner, child, ecological context, in which each link can constitute a point of strength or a breaking point in the generalization process.

If transfer requires ecological continuity across different settings, the learning environment should be understood as more than a mere backdrop for technological intervention, but rather as one of the structural links in the mediation chain that makes generalization possible. In a landscape where the boundaries between physical and digital spaces are becoming progressively permeable (Nair & Minhas, 2023), the design of the environment becomes a first-order pedagogical variable: not a mere container for inclusive practices, but a spatial, sensory, and relational condition within which the transition from the skill practiced, with the device, to the skill enacted in human relationships can effectively occur.

For students with ASD, the predictability and structuring of space are fundamental protective factors: environments organized with functionally distinct zones reduce cognitive load and foster the autonomous regulation of behavior.

In this perspective, particular attention must also be paid to the design of schools capable of accommodating diversity, a theme currently recognized as central yet still underexplored in educational research on learning environments (Alterator et al., 2022). A mindful use of space therefore implies the design of physical-digital environments capable of supporting different needs: sensory decompression zones and environments equipped for immersive technologies, quiet areas dedicated to reflection and emotional regulation, accessible layouts for students with disabilities, and interactive spaces that foster practical, collaborative activities and multiple modes of participation (Cleveland & Mahat, 2026).

It is precisely within this framework that the intentional design of the environment as an active device of ecological mediation necessarily calls into play a specific professional competence of the teacher. Their role is not exhausted in the technical mastery of devices nor in relational sensitivity alone but is configured as that of a designer of inclusive learning ecosystems, capable of coherently integrating physical spaces, digital environments, and hybrid contexts. This implies the ability to read, interpret, and pedagogically respond to the affective signals emerging from the interaction among the student with ASD, technology, and the educational environment, orienting such interactions toward the generalization of skills in real-life contexts. In this perspective, the teacher designs not only didactic activities but also the ecological conditions that make transfer possible, organizing flexible physical spaces, virtual environments, and immersive technologies as complementary elements of a single pedagogical device. Frei-Landau et al. (2023), in a study conducted on 193 pre-service special education teachers, document how the integration of digital educational neuroscience into training pathways produces four convergent outcomes: a deeper understanding of the neurological mechanisms

of neurodevelopmental disorders, an increase in professional empathy, a redefinition of the teacher's role, and a greater capacity to design situated pedagogical adaptations.

These results outline a competence that transcends technical digital literacy and requires the conscious integration of cognitive, affective, pedagogical, and environmental dimensions. It is precisely on this convergence among environment design, understanding of neuroaffective processes, and pedagogical mediation that the present contribution proposes the construct of *Digital Affective Literacy* for neurodivergent contexts.

Digital Affective Literacy identifies the teacher's ability to pedagogically inhabit learning environments, recognizing the affective signals that technologically mediated interaction generates in the student with ASD, and translating them into design choices regarding spaces, technologies, and teaching strategies that support the ecological continuity necessary for transfer. This construct is distinguished from broader digital literacy by the centrality attributed to the affective dimension of the interaction among student, technology, and environment, a dimension that Affective Computing systems make progressively more relevant and legible (Poria et al., 2017), and is configured as a formative prerequisite for that role of pedagogical director which the teacher is called upon to assume in the design of physical, digital, and hybrid learning environments oriented toward inclusion. Future research will need to empirically verify its structure and develop assessment tools for it.

9. Conclusions, limitations, and future perspectives

This contribution has highlighted how the dialogue among neuroscience, artificial intelligence, and pedagogy offers new perspectives for rethinking the inclusion of students with Autism Spectrum Disorder (ASD). Intelligent

technologies, and in particular Affective Computing systems, social robotics, and immersive environments, show significant potential in supporting the development of socio-emotional skills, provided they are embedded within intentional pedagogical design and ecologically oriented learning environments.

The scoping review presents limitations that must be explicitly acknowledged. Beyond the demographic and sampling constraints of the corpus documented in the Results — the prevalence of school-aged samples, the underrepresentation of preschool and adolescent groups, and the frequency of small samples — the design itself is deliberately bounded: a single database (Scopus) and open-access records only, which restricts coverage, notably of non-indexed and subscription literature, and introduces a selection bias; the findings should therefore be read as a first, orienting map of the field. Screening and charting were performed by the first reviewer using a piloted grid, with a second reviewer independently re-screening a random subset of the records to check consistency; given the exploratory design, full independent double screening of the entire corpus was not undertaken. Thirteen records that could not be classified with certainty at title/abstract level were not carried forward to the analysed corpus; this choice may have led to an underestimation of the evidence base, particularly with respect to mixed-age samples. The analysed studies on transfer were, moreover, predominantly conducted in clinical and rehabilitative contexts, with a significant underrepresentation of interventions in ordinary school environments.

Two research directions appear particularly promising. A first line of work could extend the scoping review presented here to further databases (e.g., Web of Science) and to non-open-access and grey literature, in order to consolidate the mapping of evidence, methodological approaches and gaps. The second

consists of the development and empirical validation of the construct of Digital Affective Literacy, defining its dimensions, indicators, and implications for the initial and continuous training of teachers, offering a reference for the design of inclusive learning environments in the era of artificial intelligence.

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