SOCIAL ROBOTICS FOR INCLUSIVE SOCIO-EMOTIONAL LEARNING

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ABSTRACT
Numerous empirical studies and field applications demonstrate how humanoid robots, conversational agents, and interactive digital environments can act as effective educational mediators, facilitating the acquisition of affective, communicative, and relational skills (Panciroli, Rivoltella, Gabbrielli & Richter, 2020; Sideraki & Drigas, 2021).
The use of social robots and intelligent systems enables the creation of structured, predictable environments with reduced emotional complexity, in which interaction is less stressful compared to direct interpersonal relationships.
At the same time, the integration of artificial intelligence systems based on machine learning, natural language processing, and multimodal analysis allows for continuous monitoring of behaviors and emotional responses, enabling dynamic personalization of educational and therapeutic interventions (Cassese, 2024; Anagnostopoulou et al., 2020).
The use of artificial agents represents a promising frontier for socio-emotional inclusion, particularly in the field of neurodiversity and special educational needs.

KEYWORDS
Social robotics; AI in education; SEL; autism spectrum disorder (ASD); inclusive pedagogy

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1.Introduction

Throughout history technology has been one of the principal driving forces behind societal transformation and development, exerting a profound influence on scientific, economic, cultural, and educational progress. It may be defined as the body of knowledge, methodologies, and practical applications that enable the design of tools, devices, and systems aimed at solving problems, optimizing processes, and addressing both individual and collective needs. Its evolution has been closely associated with humanity's capacity to develop innovative solutions capable of improving living conditions and responding effectively to the increasingly complex challenges posed by contemporary social and environmental contexts.

Technological artefacts may be interpreted as instruments that enhance human capabilities by extending physical action through tools and machines, expanding perceptual capacities through observation and communication devices, and strengthening cognitive processes through symbolic languages, mathematical models, and logical systems that support reasoning, knowledge construction, and decision-making (Menichetti, 2019). Consequently, technology should not merely be regarded as a collection of material devices but rather as a cultural and cognitive resource capable of transforming the ways in which individuals learn, communicate, and interact with their environment.

Over the last few decades, educational systems worldwide have undergone profound reforms aimed at preparing future generations to face the challenges of an increasingly interconnected, digitalized, and technologically advanced society. Within this framework, several international and national policy initiatives have played a pivotal role in redefining educational priorities. Among these, the 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly and endorsed by 193 Member States, identifies inclusive, equitable, and high-quality education as one of the fundamental Sustainable Development Goals. Similarly, the Italian National Plan for Digital Education (Piano Nazionale Scuola Digitale – PNSD), introduced through Law No. 107/2015 (*The Good School Reform*), recognizes digital transformation as a strategic priority for modernizing the Italian educational system and fostering the development of digital citizenship competencies required in contemporary society.

Alongside these educational reforms, robotics has experienced remarkable expansion, extending its application far beyond industrial production into healthcare, rehabilitation, education, and social services. Contemporary robotic systems contribute substantially to improving quality of life by supporting individuals in everyday activities, automating complex procedures, increasing operational efficiency, and performing repetitive or potentially hazardous tasks. These developments have fostered growing interest in the educational potential of robotics, particularly within inclusive learning environments where technological innovation can support personalized educational pathways.

Within this context, digital technologies increasingly function as educational mediators, creating new opportunities to transform teaching and learning processes (Salomon, 2016). Their educational value extends well beyond the acquisition of technical skills, encompassing the development of critical, conscious, and responsible digital literacy. Students are therefore encouraged not only to use technological tools effectively but also to understand their potential, recognize their limitations, avoid passive or dependent patterns of use, and employ them ethically in ways that promote both individual development and collective well-being.

From this perspective, educational robotics has emerged as one of the most innovative areas of contemporary educational research (Angel-Fernandez & Vincze, 2018). Rather than representing merely a technological innovation, educational robotics constitutes a pedagogical approach capable of integrating intelligent technologies, active learning methodologies, and inclusive educational practices. Its implementation promotes the development of cognitive, communicative, relational, and transversal competencies while encouraging students to engage in collaborative, experiential, and highly motivating learning activities. Consequently, educational robotics is expected to play an increasingly significant role in future educational innovation by contributing to the design of personalized, accessible, and learner-centred educational environments that recognize and enhance the unique potential of every student.

Within this broader framework, social robotics represents one of the most promising applications of artificial intelligence in educational contexts. Owing to their ability to interact naturally with human users through verbal communication, facial expressions, gestures, eye contact, and emotion recognition, social robots can effectively assume the role of educational mediators capable of supporting learning, participation, and the development of socio-emotional competencies, particularly among

students with Special Educational Needs (SEN) and those diagnosed with Autism Spectrum Disorder (ASD) (Pennazio, 2017).
Furthermore, an increasing body of empirical evidence indicates that many children with ASD find interactions with social robots more spontaneous, predictable, and emotionally manageable than interactions with human partners. Whereas human communication is inherently characterized by variability and unpredictability, robotic behaviour can be specifically programmed and adapted to the individual characteristics, developmental profile, and educational needs of each child. Consequently, social robots provide structured and emotionally reassuring interactional environments in which uncertainty—and the anxiety commonly associated with unpredictable social situations—is substantially reduced (Robins, Dautenhahn, Nehaniv, Mirza, & Olsson, 2005). Another particularly relevant advantage concerns the possibility of individually regulating the sensory stimuli generated by the robot. During educational interactions, auditory, visual, and other sensory feedback can be adjusted according to each child's sensory profile, thereby creating learning environments that are more accessible, individualized, and respectful of neurodiversity.

2.Social robotics and the development of socio-emotional competencies in children with Autism Spectrum Disorder

The educational inclusion of students with Autism Spectrum Disorder (ASD) has become one of the most significant challenges facing contemporary educational research and inclusive pedagogy. Addressing this challenge requires the design and implementation of educational interventions capable of responding to the heterogeneous cognitive, communicative, emotional, and social characteristics that define this neurodevelopmental condition. Over the past decades, the conceptualization of autism has progressively shifted from a predominantly medical and deficit-oriented perspective toward a bio-psycho-social framework, emphasizing not only the characteristics of the individual but also the crucial role played by environmental and contextual factors in shaping developmental trajectories. Within this perspective, inclusion should not be understood merely as the physical placement of students within mainstream educational settings; rather, it entails the creation of flexible, accessible, and responsive learning

environments that promote meaningful participation, engagement, and learning opportunities for every student.

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), Autism Spectrum Disorder is characterized by persistent impairments in social communication and reciprocal social interaction, accompanied by restricted interests, repetitive patterns of behaviour, and atypical sensory processing (American Psychiatric Association, 2014). These core characteristics substantially influence the development of socio-emotional competencies, often limiting children's ability to understand other people's intentions, interpret verbal and non-verbal communicative signals, and establish reciprocal interpersonal relationships. Nevertheless, the remarkable heterogeneity that characterizes ASD highlights the need to move beyond generalized interpretations of the disorder, recognizing that each individual presents unique learning profiles, different levels of autonomy, and distinctive strengths that should constitute the foundation of individualized educational planning.

The socio-communicative challenges associated with autism have been interpreted through several influential theoretical perspectives. Among these, Theory of Mind, originally proposed by Simon Baron-Cohen (1997), remains one of the most influential explanatory models. According to this theory, successful social interaction depends upon the ability to attribute beliefs, intentions, desires, emotions, and other mental states to oneself and to others. This cognitive capacity enables individuals to predict behaviour, interpret communicative intentions, and regulate their own responses according to the social context. Children with ASD frequently experience significant difficulties in developing Theory of Mind abilities, resulting in impairments in reciprocal social interaction, pragmatic communication, and understanding of other people's perspectives. As emphasized by Howlin et al. (1999), these limitations extend beyond verbal communication, influencing virtually every aspect of interpersonal relationships and representing one of the major barriers to successful school inclusion.

Further contributions to the understanding of socio-cognitive development have been provided by Camaioni (2003), who describes Theory of Mind as a developmental achievement emerging progressively between two and five years of age through the interaction of linguistic, cognitive, and social competencies. During this developmental period,

children gradually acquire the ability to distinguish objective reality from mental representations, recognizing that individuals may hold beliefs that differ from reality itself. This developmental process constitutes a fundamental prerequisite for empathy, intentional communication, perspective taking, and cooperative learning, all of which are essential dimensions of socio-emotional development within educational contexts.

Similarly, Cottini (2014) argues that socio-communicative difficulties should not be interpreted exclusively as manifestations of individual deficits but rather as outcomes of the dynamic interaction between the learner and the educational environment. Consequently, educational interventions should extend beyond the enhancement of cognitive functioning and explicitly address relational, emotional, and social competencies through structured learning environments, active teaching methodologies, and educational tools designed to facilitate participation and meaningful interaction.

One of the socio-cognitive domains most significantly affected in ASD concerns joint attention, namely the capacity of two individuals to simultaneously focus on the same object or event while sharing its communicative significance. Baron-Cohen (1997) identifies joint attention as one of the earliest developmental precursors of social communication because it allows children to understand that other individuals possess independent intentions, interests, and mental representations. Deficits in joint attention are frequently observed in children with ASD and are strongly associated with later difficulties in language acquisition, reciprocal interaction, and collaborative learning.

Another fundamental developmental component concerns symbolic play, which Leslie identifies as a crucial indicator of representational thinking. The ability to assign alternative meanings to objects, imagine hypothetical situations, and adopt different perspectives represents a cornerstone of both cognitive and social development. Several empirical investigations have demonstrated that children with ASD often display reduced engagement in symbolic play, preferring repetitive and highly structured patterns of interaction. These limitations are closely related to reduced mental representation abilities and further reinforce the importance of educational interventions specifically designed to foster cognitive flexibility, imagination, and social understanding (Cottini, 2014).

Emotional regulation constitutes another central aspect of ASD development. Frith (1989) argues that many behaviours traditionally

interpreted as maladaptive should instead be understood as self-regulatory responses to environments perceived as unpredictable, excessively stimulating, or emotionally overwhelming. Likewise, Surian (2002) emphasizes that reduced competence in interpreting other people's emotional states negatively affects empathic relationships and communicative exchanges, limiting social participation and increasing the likelihood of withdrawal or avoidance behaviours. Difficulties in recognizing complex emotional states—including embarrassment, irony, surprise, or shame—further compromise children's understanding of social situations and their ability to engage successfully in everyday interpersonal interactions.

Recent developments in educational research have increasingly recognized that these challenges may be effectively addressed through interventions specifically targeting Social and Emotional Learning (SEL). The SEL framework emphasizes the development of self-awareness, emotional regulation, empathy, interpersonal competencies, and responsible decision-making. Although initially developed for the general school population, its theoretical principles are particularly relevant for students with ASD because they promote educational pathways focused not only on compensating for deficits but also on enhancing well-being, participation, autonomy, and quality of life (Dale, Rispoli, & Ruble, 2022).

Within this educational framework, social robotics has emerged as one of the most innovative applications of artificial intelligence in education (Pennisi et al., 2016; Lepuschitz et al., 2018; Yang et al., 2018). Unlike conventional assistive technologies, social robots are specifically designed to engage in natural human interaction through speech, facial expressions, eye contact, gestures, and emotion recognition. Consequently, they function not merely as technological devices but as authentic mediators of social interaction capable of supporting communication, engagement, and socio-emotional development.

Current empirical evidence consistently demonstrates that many children with ASD display significantly higher levels of attention, motivation, and participation when interacting with social robots than during exclusively human-mediated interventions. According to Pennazio (2019), these positive outcomes are largely attributable to the predictability of robotic behaviour, the simplification of communicative stimuli, and the possibility of progressively adapting interactional complexity according to each child's developmental profile. By reducing the ambiguity that typically

characterizes human communication, social robots facilitate joint attention, eye contact, motor imitation, and active participation in educational activities.

Furthermore, studies investigating the educational applications of social robotics indicate that these technologies effectively support communication through imitation exercises, storytelling, cooperative learning activities, symbolic play, and structured social simulations. As highlighted by Chiappetta Cajola (2013), technology acquires genuine educational value only when integrated into intentional pedagogical planning aimed at expanding opportunities for participation and individualized learning. Likewise, Panciroli, Rivoltella, Gabbrielli, and Richter (2020) emphasize that intelligent technologies can contribute to the development of increasingly personalized educational environments capable of responding to learner variability while promoting inclusive educational practices.

The growing interest in social robotics within educational settings has led researchers to investigate not only the technological capabilities of robots but also their pedagogical potential as mediators of learning and social interaction. From this perspective, social robots should not be regarded as substitutes for teachers or therapists but rather as educational tools capable of facilitating communication, promoting engagement, and supporting the development of socio-emotional competencies within structured and intentionally designed learning environments.

Unlike traditional educational technologies, social robots are characterized by their ability to establish multimodal interactions through verbal language, facial expressions, body movements, eye gaze, gestures, and emotional feedback. These characteristics allow children to perceive robots as social partners rather than simple technological devices, creating interactional contexts that are both motivating and emotionally engaging. At the same time, because robotic behaviour is highly predictable and programmable, children with Autism Spectrum Disorder often experience lower levels of anxiety during interactions compared with those involving human partners.

Several studies have demonstrated that children with ASD frequently attribute social meaning to robotic behaviours, responding to them through eye contact, imitation, verbal communication, and joint attention more consistently than during conventional educational activities (Pennisi et al., 2016). This phenomenon appears to be associated with the reduced

complexity of robotic communication, which minimizes ambiguous social cues while maintaining sufficient interpersonal characteristics to stimulate reciprocal interaction.

One of the principal educational advantages of social robots lies in their capacity to provide individualized instruction. Artificial intelligence algorithms allow robots to continuously analyse children's behavioural responses, monitor their performance, and dynamically adapt educational activities according to individual developmental profiles. Such adaptive capabilities represent a significant advancement compared with traditional educational interventions, which generally rely on standardized instructional procedures.

Recent developments in Machine Learning and Computer Vision have considerably expanded these possibilities. By analysing facial expressions, vocal characteristics, gaze direction, body posture, and behavioural patterns, intelligent robotic systems are increasingly capable of identifying children's emotional states in real time and modifying their communicative strategies accordingly. Consequently, educational activities become progressively personalized, enabling children to experience learning situations that are neither excessively demanding nor insufficiently stimulating.

This adaptive interaction is particularly relevant for children with Autism Spectrum Disorder, whose sensory profiles often differ substantially from those of typically developing peers. Many children with ASD experience hypersensitivity or hyposensitivity to auditory, visual, tactile, or proprioceptive stimuli. Social robots can therefore regulate environmental stimulation by modifying voice volume, movement speed, facial expressions, lighting effects, or interaction frequency, thereby creating learning environments that respect individual sensory needs and reduce cognitive overload.

Another educational advantage concerns the possibility of implementing graduated social interaction. Human communication typically involves multiple simultaneous stimuli—including facial expressions, gestures, vocal prosody, eye contact, and contextual information—that may overwhelm children experiencing social communication difficulties. Social robots, conversely, allow educators to gradually increase communicative complexity by introducing one social cue at a time according to the learner's developmental progress. Such structured progression facilitates

the acquisition of increasingly sophisticated interpersonal competencies while reducing frustration and emotional distress.

Among the robotic platforms most frequently adopted in educational research, NAO has become one of the most extensively investigated humanoid robots. Owing to its programmable architecture, expressive body movements, speech capabilities, and interactive sensors, NAO has been employed in interventions targeting emotion recognition, joint attention, imitation, storytelling, collaborative learning, and executive functioning. Numerous empirical studies report significant improvements in children's motivation, engagement, and communicative participation following repeated interactions with NAO, particularly when educational activities are integrated within broader pedagogical programmes.

Similarly, the humanoid robot Kaspar, developed at the University of Hertfordshire, has been specifically designed to support children with Autism Spectrum Disorder. Unlike highly realistic humanoids, Kaspar intentionally displays simplified facial features and reduced expressive complexity, thereby facilitating emotional interpretation while avoiding sensory overload. Research indicates that interactions with Kaspar promote eye contact, turn-taking, imitation, emotional reciprocity, and cooperative play, contributing to improvements in children's social communication skills.

Another promising platform is QTrobot, which integrates advanced artificial intelligence algorithms with facial recognition systems, speech synthesis, emotion recognition, and adaptive learning mechanisms. QTrobot has been successfully employed in interventions aimed at teaching emotional vocabulary, recognizing facial expressions, improving conversational abilities, and strengthening executive functioning. Through continuous monitoring of children's responses, the robot automatically adjusts instructional strategies, providing individualized feedback and progressively increasing task complexity.

Likewise, Milo, specifically developed for educational interventions involving children with ASD, focuses primarily on teaching emotional understanding and socially appropriate behaviours. Interactive scenarios presented by Milo encourage children to identify emotional expressions, interpret everyday social situations, and practice adaptive behavioural responses. Such activities contribute to the development of emotional awareness, empathy, and social problem-solving skills, which represent fundamental dimensions of Social and Emotional Learning.

Beyond individual interventions, social robots have increasingly been integrated into collaborative learning activities, where they function as facilitators of peer interaction rather than direct instructors. In these educational settings, robots encourage children to cooperate in solving shared problems, negotiating solutions, exchanging information, and participating in group discussions. Consequently, the robot becomes a catalyst for social interaction rather than the exclusive focus of children's attention.

This collaborative dimension is consistent with Vygotsky's sociocultural theory, according to which learning emerges through mediated social interaction within the Zone of Proximal Development. Social robots may therefore be interpreted as cultural mediators capable of supporting children's development by providing temporary scaffolding that gradually decreases as learners acquire greater autonomy. Rather than replacing human mediation, robotic technologies extend teachers' instructional possibilities, allowing educational interventions to become increasingly individualized while maintaining the centrality of interpersonal relationships.

Similarly, Bandura's Social Learning Theory offers another valuable theoretical framework for interpreting the educational potential of social robots. According to Bandura, learning occurs primarily through observation, imitation, modelling, and reinforcement. Social robots provide highly consistent behavioural models that children can easily observe, imitate, and reproduce, receiving immediate feedback throughout the learning process. Such predictable interactions are particularly advantageous for children with ASD, who often benefit from repetitive practice, explicit modelling, and structured reinforcement schedules.

From a pedagogical perspective, however, the effectiveness of social robotics depends less on technological sophistication than on the quality of educational design. As emphasized by Chiappetta Cajola (2013), technological innovation acquires genuine educational significance only when embedded within carefully planned instructional activities that promote participation, autonomy, and inclusion. Accordingly, social robots should never be considered autonomous educational agents but rather components of broader pedagogical ecosystems in which teachers remain the primary facilitators of learning, emotional development, and interpersonal relationships.

Consequently, the future of social robotics in education should not be envisioned as a process of replacing teachers with intelligent machines. Instead, it lies in the creation of human-centred educational ecosystems, where artificial intelligence enhances teachers' professional practice while preserving the irreplaceable value of empathy, dialogue, and authentic human relationships. Within this perspective, technology becomes an instrument for promoting inclusion, participation, and educational equity rather than an end in itself, fully aligning with the principles of contemporary inclusive education and learner-centred pedagogy.

3. Artificial Intelligence, emotion recognition and future perspectives for inclusive education

Recent advances **in** Artificial Intelligence (AI) have profoundly transformed the educational applications of social robotics, expanding their capabilities beyond simple programmed interactions toward increasingly adaptive, intelligent, and personalized learning environments. Contemporary social robots are no longer limited to executing predefined behavioural sequences; rather, they are capable of analysing large amounts of multimodal information, interpreting human behaviour, and dynamically adapting their responses according to learners' cognitive, emotional, and communicative characteristics.

One of the most promising developments concerns the integration of Emotion Artificial Intelligence (Emotion AI)**,** also referred to as Affective Computing**,** a multidisciplinary research field introduced by Rosalind Picard (1997)**.** Affective Computing investigates computational systems capable of recognising, interpreting, processing, and responding to human emotions through the analysis of facial expressions, vocal prosody, physiological signals, body posture, gaze behaviour, and other multimodal indicators. Within educational contexts, these technologies provide unprecedented opportunities for understanding learners' emotional states throughout the learning process and for adapting instructional strategies accordingly.

Emotion recognition technologies have attracted increasing attention in interventions involving children with Autism Spectrum Disorder, primarily because socio-emotional difficulties constitute one of the core characteristics of the condition. Numerous empirical investigations indicate that many autistic children experience challenges in identifying

facial expressions, interpreting emotional cues, and understanding other people's intentions. Such difficulties frequently affect peer relationships, classroom participation, emotional regulation, and academic achievement.

Artificial intelligence offers innovative solutions by enabling robots to analyse subtle behavioural signals that may not be immediately observable by human educators. Through integrated computer vision algorithms, facial landmark detection, speech recognition systems, and multimodal machine learning models, intelligent robots can estimate children's emotional engagement during educational activities. Rather than replacing teachers' observations, these systems provide additional information capable of supporting more accurate educational decision-making and individualized intervention planning.

Recent developments in Deep Learning have significantly improved the reliability of automated emotion recognition systems. Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), Long Short-Term Memory (LSTM) architectures, and Transformer-based models have demonstrated remarkable performance in recognising complex emotional expressions across diverse populations and environmental conditions. These computational models analyse thousands of facial images, vocal recordings, and behavioural sequences to identify highly sophisticated emotional patterns that would be difficult to detect through traditional observation alone.

Within educational robotics, these advances allow social robots to recognise learners' emotional states in real time and to modify instructional interactions accordingly. For example, when a child exhibits behavioural indicators associated with frustration, cognitive overload, anxiety, or reduced motivation, the robot may simplify the task, provide additional encouragement, reduce environmental stimulation, or introduce playful interaction strategies aimed at restoring emotional balance. Conversely, when indicators of sustained attention and successful engagement are detected, the robot may progressively increase task complexity, thereby maintaining an optimal balance between challenge and competence.

Such adaptive capabilities are particularly valuable from the perspective of personalized learning. Contemporary educational research increasingly emphasizes that meaningful learning cannot rely upon standardized

instructional models but should instead recognize learner variability as a fundamental characteristic of educational systems. Students differ substantially in cognitive functioning, learning pace, sensory processing, emotional regulation, motivation, and previous educational experiences. Consequently, effective educational environments should be capable of adapting continuously to these individual differences rather than expecting learners to conform to rigid instructional frameworks.

This educational philosophy is fully consistent with the principles of Universal Design for Learning (UDL)**,** which advocate the proactive design of flexible learning environments capable of accommodating learner diversity from the outset rather than through subsequent accommodations. According to the UDL framework, educational experiences should provide multiple means of engagement, multiple means of representation, and multiple means of action and expression. Social robots supported by artificial intelligence offer concrete opportunities to operationalize these principles by continuously adapting communication modalities, instructional supports, sensory stimulation, and learning activities according to each learner's individual profile.

Another particularly significant contribution of artificial intelligence concerns the collection and analysis of educational data. Intelligent robotic systems continuously generate extensive datasets regarding children's responses, interaction patterns, communicative behaviours, emotional fluctuations, and learning progress. When analysed responsibly and ethically, these data may support teachers in monitoring educational outcomes, identifying emerging learning needs, and evaluating the effectiveness of individualized interventions over time.

Such possibilities also open new perspectives for the development of learning analytics, enabling educators to make evidence-based instructional decisions. Rather than relying exclusively on subjective observations, teachers may integrate quantitative behavioural indicators with qualitative educational assessments, thereby obtaining a more comprehensive understanding of learners' developmental trajectories. This integrated approach may prove particularly valuable when planning Individualized Education Programs (IEPs) for students with Autism Spectrum Disorder, as it facilitates continuous monitoring and timely adjustments to educational objectives.

Despite these considerable opportunities, the integration of artificial intelligence within educational contexts also raises important ethical, pedagogical, and social concerns. One of the principal issues relates to the collection, storage, and processing of sensitive personal data generated during human–robot interactions. Facial expressions, voice recordings, physiological indicators, and behavioural profiles constitute highly sensitive information that requires rigorous protection in accordance with international privacy regulations and ethical standards.

Equally important is the issue of algorithmic transparency**.** Artificial intelligence systems increasingly influence educational decision-making processes; however, many advanced machine learning models remain difficult to interpret due to their "black-box" nature. From an educational perspective, teachers, families, and learners should be able to understand the rationale underlying automated recommendations, emotional classifications, or adaptive instructional decisions. Consequently, current research increasingly advocates the adoption of Explainable Artificial Intelligence (XAI) approaches capable of enhancing transparency, accountability, and trustworthiness within educational AI applications.

Another critical issue concerns the potential risk of excessive technological dependence. Although social robots can substantially enhance educational experiences, they should never replace authentic human relationships. Emotional development fundamentally depends upon meaningful interpersonal interactions characterized by empathy, reciprocity, shared intentionality, and genuine emotional engagement. Robots may effectively support these processes, but they cannot reproduce the complexity, authenticity, and moral dimensions of human relationships. Consequently, social robotics should always be conceived as complementary to—rather than substitutive of—teachers, families, and peers.

From a pedagogical standpoint, the successful integration of artificial intelligence into educational practice also requires substantial investment in teacher professional development. Educators need competencies that extend beyond technical operation of robotic systems. They must understand the pedagogical implications of intelligent technologies, critically evaluate their educational effectiveness, interpret algorithmic outputs responsibly, and integrate technological innovation within evidence-based instructional practices. Digital competence therefore

becomes inseparable from pedagogical competence and ethical responsibility.

Future research should focus not only on improving technological performance but also on evaluating the long-term educational impact of artificial intelligence and social robotics. While many existing studies report encouraging short-term outcomes regarding attention, motivation, and social interaction, considerably less evidence is available concerning the durability of these improvements, their transfer to naturalistic social environments, and their influence on children's overall quality of life. Longitudinal, multidisciplinary, and ecologically valid research designs will therefore be essential for determining the actual contribution of intelligent robotics to inclusive education.

Ultimately, the future of social robotics should not be measured exclusively by technological sophistication but by its capacity to contribute to more equitable, accessible, and human-centred educational systems**.** Artificial intelligence should remain a means rather than an end, supporting educational practices grounded in inclusion, participation, emotional well-being, and respect for learner diversity. Only through the integration of technological innovation, pedagogical knowledge, psychological understanding, and ethical responsibility will social robotics fully realize its potential as a transformative resource for inclusive education in the twenty-first century.

4.Conclusion

The rapid evolution of artificial intelligence and social robotics is profoundly reshaping contemporary educational research, offering unprecedented opportunities to design more inclusive, personalized, and learner-centred educational environments. The evidence reviewed throughout this study indicates that social robots constitute valuable pedagogical mediators capable of supporting the development of socio-emotional competencies, enhancing communication, and facilitating meaningful participation among children with Autism Spectrum Disorder (ASD). Their educational value extends beyond technological innovation, as they provide structured, predictable, and adaptive interactional contexts that can reduce social anxiety, increase motivation, and promote engagement in learning activities.

The literature consistently demonstrates that social robots can effectively foster fundamental developmental competencies, including joint attention, imitation, emotional recognition, communicative reciprocity, and collaborative interaction. These competencies represent essential prerequisites for both academic learning and social participation and are frequently compromised in children with ASD. Consequently, the integration of social robotics within educational settings should not be interpreted merely as the introduction of an innovative technological device but rather as the implementation of a pedagogical strategy capable of expanding learning opportunities while respecting individual developmental characteristics.

Nevertheless, the findings emerging from the current body of research also require careful and critical interpretation. Although numerous empirical studies report encouraging outcomes, the available evidence remains characterized by considerable methodological heterogeneity. Differences in sample sizes, intervention duration, assessment instruments, robot platforms, and outcome measures often limit the comparability and generalizability of research findings. Many investigations involve relatively small samples, short-term interventions, or highly controlled laboratory environments, making it difficult to determine whether the observed improvements are maintained over time or transferred to authentic educational and social contexts.

Another significant limitation concerns the tendency of some studies to focus primarily on technological performance while devoting comparatively less attention to pedagogical variables. The effectiveness of social robots does not depend exclusively on advances in artificial intelligence or engineering but rather on the quality of instructional design, the educational competence of teachers, and the meaningful integration of technology within evidence-based pedagogical practices. In other words, technology alone cannot guarantee educational innovation. Without clear learning objectives, appropriate methodologies, individualized planning, and continuous educational mediation, even the most sophisticated robotic systems risk becoming merely attractive technological devices with limited educational impact.

From this perspective, one of the principal challenges for future research concerns the need to move beyond technology-centred approaches towards genuinely human-centred educational ecosystems**.** Social robots should not be conceived as autonomous educational agents or as

substitutes for teachers, therapists, or families. Instead, they should be understood as complementary tools capable of enriching educational interactions, facilitating communication, and supporting individualized learning pathways. The educational relationship remains fundamentally grounded in empathy, dialogue, trust, and emotional reciprocity—dimensions that cannot be replicated by artificial systems, regardless of their computational sophistication.

Particular attention should also be devoted to the ethical implications associated with the increasing use of artificial intelligence in educational settings. The collection and processing of sensitive behavioural, emotional, and biometric data require rigorous safeguards regarding privacy, informed consent, transparency, and accountability. Furthermore, the growing reliance on machine learning algorithms raises important questions concerning algorithmic bias, explainability, equity, and the potential consequences of automated decision-making processes. Future developments should therefore prioritize Explainable Artificial Intelligence (XAI) and ethical-by-design approaches capable of ensuring that technological innovation remains aligned with fundamental educational values and children's rights.

Equally important is the issue of teacher professional development. The successful integration of social robotics into educational practice requires educators to acquire not only technical competencies but also advanced pedagogical, ethical, and interdisciplinary knowledge. Teachers must be capable of critically evaluating technological tools, interpreting algorithmic outputs, designing individualized interventions, and integrating robotic systems within inclusive educational methodologies. Consequently, teacher education programmes should increasingly incorporate topics related to artificial intelligence, educational robotics, digital pedagogy, and data ethics as integral components of professional preparation.

From an educational perspective, the findings discussed in this article reinforce the importance of adopting a holistic conception of inclusion. Inclusive education cannot be reduced to the physical placement of students with disabilities within mainstream classrooms; rather, it requires the creation of learning environments capable of recognizing learner diversity as a resource rather than a limitation. Social robotics may contribute significantly to this objective by supporting differentiated instruction, enhancing accessibility, promoting active participation, and

facilitating the development of socio-emotional competencies that constitute the foundation of lifelong learning and social inclusion.

Future research should therefore adopt longitudinal, interdisciplinary, and ecologically valid research designs capable of investigating not only immediate educational outcomes but also the long-term effects of social robotics on children's cognitive development, emotional well-being, social participation, academic achievement, and quality of life. Particular attention should be devoted to evaluating the transferability of acquired competencies from structured robotic interactions to naturalistic social environments, including classrooms, families, and peer relationships. Moreover, comparative studies involving different robotic platforms, educational methodologies, and learner profiles would contribute substantially to identifying the conditions under which social robotics can produce the greatest educational benefits.

In conclusion, social robotics should not be regarded simply as an emerging educational technology but as part of a broader transformation in the ways educational systems conceptualize learning, inclusion, and human development. Its future success will depend less on continuous technological advancement than on the capacity of educators, researchers, engineers, psychologists, and policymakers to collaborate in designing educational ecosystems where artificial intelligence serves genuinely human purposes. Only by maintaining the person, rather than the technology, at the centre of educational innovation will it be possible to harness the full potential of social robotics as a meaningful resource for promoting equity, participation, socio-emotional development, and inclusive education in the twenty-first century.

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