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The integration of Artificial Intelligence and Robotics Technologies in Teaching Social and Cognitive Skills to Children with ASD

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Abstract. This study investigates the ethical, educational, and methodological implications of using artificial intelligence (AI) and robotics in supporting children with Autism Spectrum Disorder (ASD) within educational settings. It explores both the potential benefits and the limitations of these technologies in fostering cognitive and social skills development. The research is based on a critical literature review of current empirical studies concerning the application of AI and robotic tools in special education for children with ASD. The selection of studies adhered to strict inclusion criteria, focusing on those conducted within formal or informal educational contexts. Emphasis was placed on methodological transparency, evaluation criteria, and the socio-cultural context of implementation. Findings reveal promising opportunities for differentiated instruction, personalized learning, and low-anxiety skill repetition through AI and robotics. However, significant concerns remain regarding data privacy, algorithmic bias, and the reduction of human interaction, which is crucial for emotional and social development. The limited number of high-quality studies and small, culturally homogeneous samples also pose challenges to the generalizability of the results. The study highlights the necessity of ethically responsible, inclusive, and pedagogically sound technological integration in special education. Future research should prioritize large-scale, cross-cultural, and longitudinal studies, integrating interdisciplinary collaboration among educators, psychologists, AI specialists, and developmental experts. The effective use of AI should complement rather than replace human interaction, reinforcing inclusive education practices that center on the needs of children and families.

Keywords. Autism Spectrum Disorder, artificial intelligence, robotics, social skills, cognitive skills

A. Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by difficulties in social interaction, communication, and the presence of repetitive behaviors [1] According to the World Health Organization [2], ASD affects approximately 1 in 100 children globally, with symptoms varying in intensity and presentation. One of the most significant challenges faced by children with ASD involves the development of social and cognitive skills. Difficulties in understanding social cues, an inability to establish reciprocal relationships, and a strong preference for structured and predictable environments impact their daily functioning

[3]. Additionally, research indicates that children with ASD frequently experience deficits in executive functioning and cognitive flexibility, which may hinder their adaptability to new situations and problem-solving abilities in everyday life. ASD is marked by a high degree of heterogeneity, as affected children exhibit varying degrees and types of impairments. While all children with ASD encounter challenges in social interaction and communication, the specific manifestations and needs differ considerably. Some may present with mild social impairments, whereas others may face severe communication difficulties and struggle to interpret social signals [4]. This heterogeneity necessitates a tailored approach to intervention, as strategies effective for one child may not be applicable to another. Therefore, it is essential to consider each child's individuality in order to develop personalized and adaptive interventions that meet their unique needs. Moreover, this diversity underscores the importance of utilizing diverse technological tools and strategies such as artificial intelligence and robotics which can be customized to offer individualized support for the enhancement of social and cognitive skills [5]. For children with ASD, communication often extends beyond verbal expression to include non-verbal cues such as body language, facial expressions, and gestures. However, many children with ASD have difficulty understanding or using these non-verbal signals. This limitation complicates social interactions, as they may fail to recognize or appropriately respond to the emotional or social cues within their environment, thereby affecting their ability to form relationships and integrate socially [6]. Recognizing and interpreting non-verbal cues is therefore critical for improving communication and social interaction in children with ASD. Despite their challenges, these children can benefit from targeted strategies and tools that enhance their ability to decode social and emotional signals such as training in body language recognition and facial expression interpretation. Technological tools, including robotic systems and artificial intelligence applications, offer a safe and controlled environment in which children can practice and develop these skills. The cultivation of social and cognitive skills is pivotal for children with ASD, as it fosters their social inclusion and enhances their daily functioning. Social skills enable children to interact and communicate effectively with others, while cognitive skills underpin learning and problem-solving abilities. Nevertheless, many children with ASD experience difficulties in these domains, which can lead to social isolation and emotional difficulties [3].

Traditional intervention methods, such as Applied Behavior Analysis (ABA) and various psychological therapies, focus primarily on repetition and the systematic reinforcement of specific behaviors. For instance, ABA utilizes positive reinforcement to teach social skills and other target behaviors [7]. Despite their documented successes, these conventional approaches are often confined to rigid and highly structured settings, which may hinder the promotion of spontaneous social interaction and limit the personalization of the intervention. Additionally, they face several challenges, including the need to accommodate diverse learning styles, high financial costs, limited availability of trained professionals, and difficulties in generalizing acquired skills to naturalistic environments. Furthermore, traditional interventions do not always respond adequately to the individual needs of each child and may require prolonged and intensive engagement without guaranteed outcomes [8]. Technological advancements have introduced new, innovative approaches aimed at overcoming these limitations. The integration of artificial intelligence and robotics has shown significant effectiveness across various domains, particularly in supporting individuals with ASD. These technologies offer several advantages over traditional methods. Firstly, robots and AI-based applications can deliver continuously adaptive and uninterrupted instruction, independent of human intervention, thereby reducing the need for intensive supervision and repetitive

professional planning. More specifically, communication and interaction with robots may provide children with opportunities to experiment with and explore social scenarios without the stress typically associated with real-life social encounters [9].

Artificial Intelligence (AI) is a field within computer science concerned with the development of systems and computational models that enable machines to perform tasks traditionally requiring human intelligence. These tasks include learning, logical reasoning, problem-solving, language processing, and perception. AI aims to create machines capable of mimicking human thought and learning processes, allowing them to recognize patterns, make decisions, and interact with their environment [10]. The core technologies that underpin AI include machine learning (ML), wherein systems are “trained” using data to improve automatically without being explicitly programmed for each individual task. These algorithms are applied in various domains, including data analysis, image processing, and trend forecasting, either through supervised or unsupervised learning approaches. One of the principal advantages of ML lies in its ability to learn from data and autonomously perform functions with increasing accuracy over time [11]. A more advanced form of this technology is deep learning, which employs neural networks to recognize complex patterns and make decisions based on the analysis of vast amounts of data [10]. Through deep learning, computational models learn incrementally from data via multiple layers of abstraction and analysis. Deep learning represents one of the most contemporary and widely adopted approaches in the field, driving major innovations through continuously evolving techniques that often surpass traditional methods and accelerate technological progress [12; 13]. AI has profoundly influenced numerous aspects of everyday life, and education is no exception. It has emerged as a powerful driver of change in educational contexts, offering new opportunities to enhance learning processes. Its contributions are widely acknowledged, particularly in enabling personalized instruction tailored to individual student needs, automating educational tasks, and supporting the development of innovative teaching methodologies. Through data processing and machine learning, AI can deliver personalized support that improves both learners’ comprehension and performance [14]. With the continuous advancement and evolution of technologies, AI has the potential to significantly enhance educational processes by tailoring learning experiences to individual student needs and providing novel tools for both educators and learners. From personalized learning systems and intelligent teaching assistants to automated assessments and interactive learning platforms, AI promises to reshape the way we teach and learn. Despite its vast potential, several challenges remain, including ethical considerations regarding its use and the urgent need to train educators in effectively implementing these emerging technologies [15].

Initially, AI emerged as a collection of computer-based technologies and later evolved into intelligent online educational systems. Over time, its development has expanded to include embedded computational systems, humanoid robots, and internet-based chatbots, which can operate either autonomously or in collaboration with educators. These technologies have enabled teachers to manage administrative tasks, such as student assessment and grading, with greater accuracy and efficiency, while simultaneously improving the quality of instruction [16]. Additionally, through the application of machine learning, educational content and curricula have been tailored to meet the individual needs of students. This approach has contributed to the personalization of teaching and the deeper understanding of subject matter, enhancing the overall educational experience and elevating the quality of learning [16]. For typically developing children, AI can play a significant role in the development of communication skills, much like it does for learners of the English language. Through personalized and interactive learning experiences, children can improve their speaking, listening, reading, and writing

abilities. For instance, intelligent language-learning applications can adapt content according to the student's level and needs, while chatbots provide a conversational environment that fosters verbal communication. Moreover, adaptive learning platforms can offer immediate feedback, allowing students to refine their skills through targeted practice. These technologies contribute to better knowledge retention and engagement by offering a more dynamic and individualized learning experience [17]. AI applications are diverse, ranging from voice and image recognition systems to autonomous vehicles and personalized therapeutic solutions. The primary aim of artificial intelligence is to improve processes and efficiency, as well as to provide new tools for solving complex problems and supporting human needs as is the case with ASD. Challenges in emotional expression and recognition are addressed by an educational game focused on emotions called EMOTIFY. This software, utilizing artificial intelligence and specifically machine learning, evaluates vocal tone to identify emotions, thereby helping children with ASD to imitate and acquire communication-enhancing skills [18].

Robotics, a branch of engineering and technology, focuses on the design, construction, and operation of robots, machines capable of performing tasks either autonomously or under human guidance. Robots typically employ sensors and software to interact with their environment and execute tasks ranging from simple to complex. Applications of robotics span from industrial automation to healthcare and education, including social interaction robots. For individuals with ASD, robotics has proven extremely beneficial, serving as a tool to enhance social and communication skills by offering safe, non-judgmental interactions. Furthermore, robotics promotes autonomy by delivering personalized and interactive educational tools, supporting greater social integration and personal development. Notably, the development of "social robots" such as NAO and PARO has contributed to improving communication and interaction among children with ASD. These robots serve as consistent and predictable "companions" that foster social engagement in a controlled, comfortable environment where children feel safe to express emotions and participate in learning-oriented activities [19; 20]. The integration of artificial intelligence into robotics has opened new frontiers for the development of intelligent robots capable of interacting with individuals and adapting to their specific needs in a personalized manner. The combined use of AI and robotics enables robots to process real-time data, recognize and analyze human behavior, and adjust their responses accordingly. In the case of individuals with ASD, this technology offers significant benefits by functioning as a means to promote social interaction and education. AI allows robots to recognize the emotional states and needs of individuals with ASD, improving communication and reinforcing their self-esteem. Additionally, through continuous learning and adaptation, robots can provide flexible and personalized interventions, thus enhancing the overall quality of life for individuals with ASD. The capacity of robots such as *Kaspar*, to adapt to each child's individual needs is of critical importance in the education of children with ASD, as it effectively supports the development of their skills across various and diverse settings [21; 22].

Modern technologies enable the development of personalized solutions tailored to the needs of individuals with ASD, offering new possibilities in communication, learning, and daily life [23]. Artificial intelligence, through data analysis and real-time program adaptation, contributes to a deeper understanding of individual behaviors and needs, while robotics integrates interactive tools that enhance social and communication skills. The combined use of these technologies has yielded significant positive outcomes in promoting autonomy, social inclusion, and overall quality of life for individuals with ASD, rendering them essential tools in contemporary intervention and support. Efforts to integrate these evolving technologies into educational practice underscore the need for targeted interventions and the formulation of

appropriate policies that ensure both accessibility and the ethical use of such systems [23]. Despite their effectiveness, the ongoing discussion around the challenges and potential of technology in special education has mainly focused on the necessity of adopting innovative tools to support children with ASD, taking into account their social and cultural contexts.

This study aims to explore the use of artificial intelligence and robotic technologies in the development of social and cognitive skills in children with ASD. Specifically, it examines tools that foster the development of social skills such as communication, understanding social cues, and building relationships, as well as tools that contribute to the development of cognitive skills including memory, attention, and problem-solving. By investigating contemporary tools, methods, and practices, the study seeks to evaluate the effectiveness of these technologies, identify challenges and ethical issues associated with their use, and provide guidelines for their responsible and targeted implementation. Ultimately, it aims to contribute to the enhancement of educational practice and the improvement of the quality of life for children with ASD. Investigating this subject is of vital importance for several reasons. First, the lack of appropriate support methods may hinder the development of children with ASD and exacerbate their social exclusion. Second, the ongoing advancement of technology presents opportunities for personalized approaches that can address the specific needs of each child. Finally, understanding the effectiveness and ethical challenges related to these technologies is crucial for ensuring their responsible and meaningful application. With these considerations in mind, the study has been structured around the following principal aims:

1. To explore AI and robotic technologies used for the development of social skills in children with ASD.
2. To investigate AI and robotic technologies that contribute to the enhancement of cognitive skills, such as memory, attention, and problem-solving.
3. To assess the effectiveness of these technologies by analyzing data from previous studies and real-world applications.
4. To examine the challenges and ethical issues arising from the use of such technologies in the education of children with ASD.

B. Method

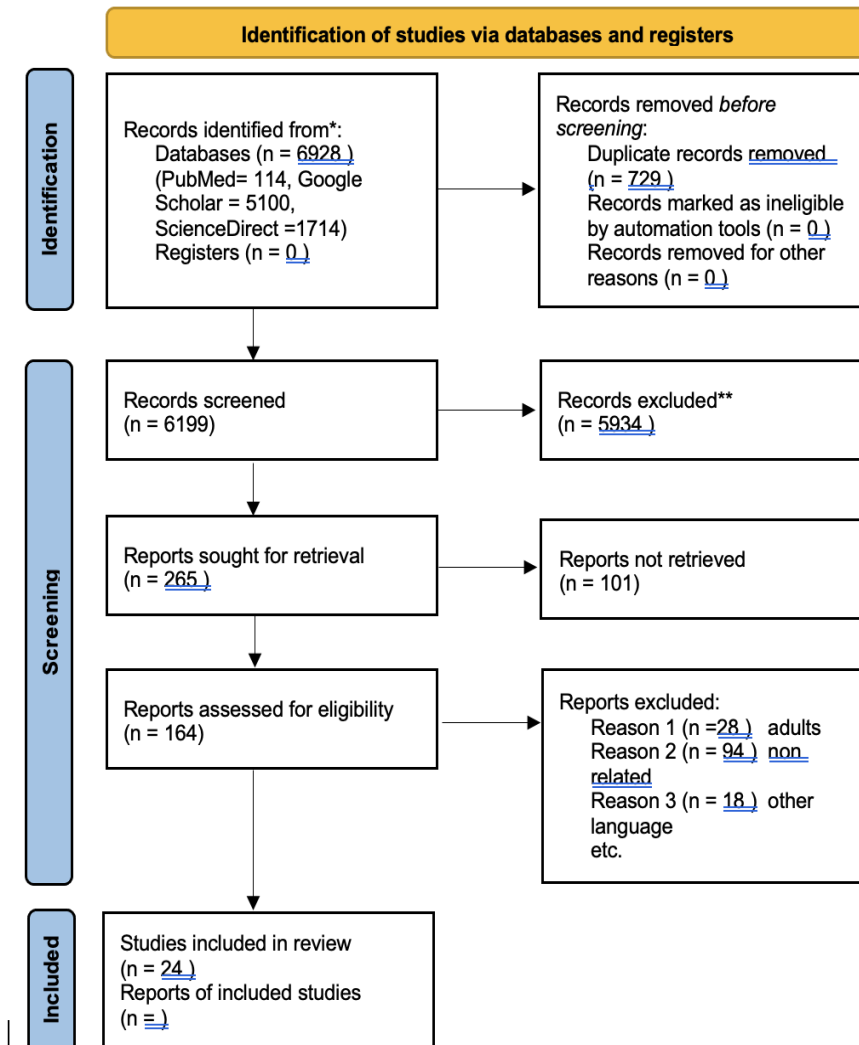
The literature review was conducted through a comprehensive search of scientific sources in databases such as PubMed, Google Scholar, and ScienceDirect, covering the last five years (2020–2024). The search strategy employed a combination of the following keywords: *“autism spectrum disorder” OR “ASD” AND “artificial intelligence” OR “AI” OR “machine learning” OR “deep learning for chatbots” OR “robots” AND “educat” OR “learn*” AND “social skills” OR “cognitive skills”**.

Based on specific inclusion and exclusion criteria, a total of 24 relevant studies were identified. The inclusion criteria comprised peer-reviewed articles published in English, focusing on children aged 2 to 18 years. Additionally, eligible studies were those that explored the enhancement of social and cognitive skills in children with ASD through the implementation of artificial intelligence and robotic technologies.

Conversely, exclusion criteria involved studies that did not investigate the use of AI or robotics in supporting social or cognitive development in children with ASD. This included research focusing on other aspects of ASD intervention, such as diagnosis, the development of unrelated skills, or medical treatment approaches. Furthermore, studies involving adult populations were excluded from the review.

The selection process and results of the literature review are illustrated in the following PRISMA-style flow diagram [61].

Flow Diagram 1. PRISMA 2020



C. Results

Social Skills

The utilization of innovative technologies to support the social and communicative development of children and adolescents has expanded significantly, with a wide range of tools incorporating AI, robotics, Internet of Things (IoT) sensors, virtual environments, and conversational platforms.

Artificial Intelligence (AI)

AI is widely used to enhance communication and social interaction in children and adolescents with ASD. Through user-friendly and adaptive environments, conversational agents (chatbots) and educational applications facilitate the development of language skills and improve emotion recognition. For example, LISSA, an AI-powered system designed for teenagers, promotes verbal communication and social engagement through dialogic interaction

[24]. Similarly, applications such as Livox and Vithea-Kids aim to expand vocabulary and support broader social participation using machine learning techniques [25]. Conversational digital assistants offer structured dialogues that assist children in expressing emotions and managing inappropriate responses, thus providing precise and personalized interventions [26]. In a related study, a child-friendly Chinese chatbot facilitated communication through language and emotion-based interaction [27].

Robotics

Robotic technologies have been employed in numerous research initiatives aimed at empowering children socially. Through gesture imitation, facial expression recognition, and interaction, social robots create a safe and accessible learning environment. For instance, the NAO robot has been used to promote social skills through the imitation of gestures and movements [28]. While other robots focus on facial expression detection such as smiles and eye contact, providing early social stimuli [29]. Social robot-based interventions enhance communicative abilities through interactive experiences and imitation [30]. Moreover, the use of robotics in playful contexts fosters emotional expression, cooperation, and participation, offering positive motivation for social engagement [31]. The Pepper robot, powered by OpenAI technology, can recognize speech, emotions, and facial expressions, thereby supporting the development of social skills [32].

AI and Robotics Integration

The integration of AI with robotics enables the delivery of more comprehensive interventions. Tools such as FECTS, which incorporate emotion-based facial expression imitation capabilities, significantly contribute to improving social communication [33]. Similarly, approaches utilizing deep neural networks facilitate empathetic dialogue, strengthening emotional connections [27]. Machine learning-supported interactive robots are also used to promote social inclusion and communication in children [34].

AI and Internet of Things (IoT)

AI and IoT are employed in novel ways to detect and predict communicative behaviors. Sensors that track hand, head, and finger movements embedded in wearable devices, such as gloves, are used to predict sign language, thereby enhancing communication and engagement among children [35]. Additionally, IoT sensors combined with AI are used to recognize emotional states in children aged 4–12, supporting more effective social interaction [36].

AI and Virtual/Augmented Reality (VR/AR)

Virtual and augmented reality technologies offer new opportunities for social skills education. VR-based systems monitor eye movement and heart rate to support emotional awareness and communication [21]. Moreover, educational software integrating VR, AI, and AR can guide speech initiation, analyze communicative behavior, and propose individualized intervention strategies [37].

Multimodal Approaches

Some interventions employ a combination of AI, robotics, and digital applications. A notable example includes the combined use of the Kaspar robot, the LIFEisGAME platform, the Empower Me application, and the Milo robot, which collectively help children recognize emotions and improve social interaction on multiple levels [38]. The results discussed above are summarized in Table 1.

Table1. Identified Articles

Source	Assistive Tool	Age Group	Intervention Description	Objective	Technology
Ali et al., 2020	LISSA	13–17 years	Verbal communication enhancement	Development of social skills	AI
Barua et al., 2022	Kaspar robot, LIFEisGAME, 'Empower Me' app, Milo	Children	Emotion recognition during interaction with the application	Enhancement of social interaction	AI
Abdel Hameed et al., 2022	IoT	4–12 years	Emotion recognition	Enhancement of social interaction	AI, Machine Learning, IoT
Ullah et al., 2023	IoT (glove)	Children	Gesture sensors for hand, head, and finger movements; sign language prediction (96% accuracy)	Communication development, social interaction	AI and IoT
Qidwai et al., 2020	NAO robot	7–11 years	Imitation of gestures and communicative movements	Development of social skills	Robotics
Kim et al., 2021	Robot (NA)	9.6–9.8 years	Facial expression and smile recognition	Early social skills enhancement	Robotics
Ghiglino et al., 2021	Social robot	Mean age: 5.79 years	Interaction and imitation of movements	Improvement of communication abilities and responsiveness in social contexts	Robotics
Alabdulkareem et al., 2022	Robots	Children	Child-robot interaction; motivation for social engagement	Promotion of interaction, communication, emotional expression,	Robotics

				behavior, collaboration, active participation, and satisfaction	
Bertacchini et al., 2023	Pepper robot	Children	Speech, emotion, and facial expression recognition	Enhancement of social interaction	AI and Robotics (OpenAI technology)
Wan et al., 2022	FECTS	3–8 years	Facial expression imitation based on emotional cues	Development of social and communication skills	AI and Robotics (Deep Learning)
Xuan Li et al., 2020	Chinese chatbot	Children	Child-chatbot interaction in a friendly conversational environment	Enhancement of social and communication skills	AI and Robotics (Deep Neural Network)
Hadri & Bouramoul, 2023	Chatbot	Children	Conversation initiation, guided dialogue, emotion expression, behavioral regulation	Communication development (98% model accuracy)	AI and Robotics (Deep Learning)
Iannone & Giansanti, 2023	AI-assisted tools, interactive robots with AI	Children	Interaction to support communication	Enhancement of social skills	AI and Robotics (Machine Learning)
Hughes-Roberts et al., 2022	Virtual Reality (VR)	Children	Eye-tracking, heart rate monitoring, emotion recognition	Improvement of communication	AI, Machine Learning, and VR
Adako et al., 2024	VR software, AI apps	Children	Guided speech initiation, analysis and support of communication behaviors, emotion and	Enhancement of social skills, emotional awareness and regulation,	AI, VR, and AR

			facial expression recognition	personalized tools and learning methods	
Farzana et al., 2021	Livox, Vithea-Kids	Children	Vocabulary development	Improvement of communication and social skills, enhancement of social participation	AI (Machine Learning) and AR

Overall, as illustrated in the accompanying table, the application of innovative technologies has significantly contributed to the enhancement of social skills in children with ASD. These technologies offer personalized interventions that facilitate social interaction, communication, and emotional expression. Existing studies indicate that interactive tools such as social robots, chatbots, and virtual reality environments support children in improving their ability to initiate and maintain conversations, recognize emotions, and actively participate in social situations. AI, robotics, VR, AR, and IoT, as well as the integration of these technologies, represent the primary means employed in such interventions. These tools enable more natural and adaptive forms of communication, thereby promoting social inclusion. The combined use of these technologies demonstrates substantial potential as effective tools for the education and support of children with ASD, playing a vital role in fostering their social integration and enhancing their overall quality of life.

Cognitive Skills

The integration of advanced technological tools in the educational and learning process has led to the emergence of innovative interventions aimed at enhancing cognitive functions. Through applications of artificial intelligence, robotics, augmented reality, and sensor-based systems, children are encouraged to actively participate in learning, develop problem-solving abilities, and reduce attention-related challenges.

Artificial Intelligence (AI)

Artificial intelligence is widely used to personalize learning, support memory and perception, and maintain focus. Educational software and interactive applications such as Math Bingo, Word Wagon, Intro to Letters, and Squizzy offer playful learning experiences that promote perceptual and memory development, thereby enhancing cognitive growth through increased engagement [38].

Interventions involving smartwatches equipped with sensors track physical activity and heart rate to monitor attention span and regulate focus during learning activities, promoting cognitive stability [39].

Additionally, AI-powered wearable technologies, such as AR glasses and headsets, offer a holistic approach to educational support, aiding in emotional regulation, attention control, and overall cognitive enhancement [40].

Robotics

Robotic interventions contribute to the development of cognitive skills through motor engagement, experiential learning, and interactivity. Systems such as PvBOT assist with the understanding of numerical concepts, such as place value, by encouraging active participation

and eliciting positive emotions, which in turn significantly improve performance [41]. The social robot NAO has demonstrated effectiveness in enhancing both attention and cognitive abilities through gesture imitation [28], while Pepper supports critical thinking, language comprehension, and decision-making processes, offering multifaceted opportunities for cognitive development [32].

Combination of AI and Robotics

Interventions that combine AI with robotic systems provide personalized support based on the monitoring of behavior and performance. A notable example is KIWI, a socially assistive robot that engages children in math games while collecting audio-visual performance data, achieving accuracy improvements of up to 90% [42]. Other interventions employ robots to support the acquisition of foundational skills such as literacy and numeracy, creativity, and initiative-taking—reinforcing problem-solving, memory, and attention [31].

Humanoid robots and AI-driven tools also create opportunities to teach desirable behaviors and strengthen cognitive functions tailored to each child’s individual needs [34]. Additional findings related to cognitive skills enhancement are presented in Table 2

Table 2. Additional Results on Research

Source	Assistive Tool	Age Group	Intervention Description	Objective	Technology
Deng & Rattadilok (2022)	Smartwatch – sensors	5.3 years	Monitoring movement and heart rate through wearable sensors	Enhancement of cognitive skills and reduction of attention deficits	AI
Barua et al. (2022)	Math Bingo, Word Wagon, Intro to Letters, Squizzy educational software	Children	Improvement of perception and memory through interactive games and educational applications	Personalized intervention effectiveness, increased learning interest, cognitive development	AI
Nguyen & Huang (2024)	AR glasses and headphones	Children	Holistic educational support and student engagement	Active participation, reduced distractions, emotional self-regulation, and cognitive enhancement	AI (machine learning)
Arshad et al. (2020)	PvBOT	10–13 years	Learning number placement	Active engagement, positive	Robotics

			through robotic interaction	emotions, significantly improved scores, cognitive skill enhancement	
Qidwai et al. (2020)	NAO robot	7–11 years	Mimicking communicative gestures and movements	Improved cognitive performance and reduced inattention	Robotics
Bertacchini et al. (2023)	Pepper robot	Children	Decision-making, critical thinking, natural language interaction	Improvement in cognitive abilities	AI and Robotics (OpenAI technology)
Jain et al. (2020)	Social assistive robot KIWI	3–11 years	Math-based gaming with visual and auditory performance data collection	Cognitive skill enhancement and performance improvement with up to 90% accuracy	AI and Robotics (machine learning)
Alabdulkareem et al. (2022)	Robots	Children	Alphabet and number learning, encouragement of creativity and initiative, enhancement of perception	Positive impact on problem-solving, memory, attention, and general cognitive functions	AI and Robotics
Iannone & Giansanti (2023)	Humanoid robots, AI tools	Children	Training in desired behaviors and cognitive skills	Personalized cognitive development based on individual needs	AI and Robotics (machine learning)

The enhancement of children's cognitive abilities through technological interventions represents a critical area of research and practical application, particularly for children with ASD. The technological solutions employed aim to improve memory, attention, decision-making, problem-solving, and perception, while also fostering creativity and active engagement in the learning process. Digital and robotic tools enable personalized interventions by providing tailored educational environments that stimulate children's interest in learning. To this end,

various technologies are utilized, including AI, robotics, Virtual and VR and AR, as well as sensors and wearable devices. Interactive games and applications further support memory and perception development, making the learning process more engaging. AR and VR technologies, in particular, offer immersive learning experiences that contribute to enhanced attention and emotional regulation. Overall, the use of these technologies contributes significantly to the improvement of children's cognitive skills, strengthening the educational process and offering personalized support for their developmental needs.

Effectiveness

The use of AI and social robots in the education of children with ASD has proven particularly effective, offering personalized learning experiences and improving social interaction [38]. Machine learning tools adapt content to each child's individual needs, enhancing knowledge retention and participation in the learning process [26]. In particular, social robots have demonstrated high accuracy up to 90% in detecting children's engagement, despite the variability of data across users and sessions (Jain et al., 2020). Studies indicate that interaction with robots can significantly improve children's communication and social skills, as the robots adapt to the students' behavior and respond accordingly (Arshad et al., 2020). After a 10-week intervention, children began to imitate the robot's behavior, recognize its gestures and eye contact, and initiate interactions. Significant improvement in communicative skills was observed, as the robot's simplified behavior was easier to understand, thus enhancing eye contact and whole-body engagement. The results suggested that robot-assisted interventions were more effective than traditional methods for teaching social skills. Moreover, the positive effects of interaction persisted even when children communicated with adults without the robot's presence. The gradual imitation of the robot's gestures and eye contact encouraged spontaneous social interaction, with lasting benefits even in human-only interactions. Overall, Jain et al. (2020) [42] conclude that using machine learning algorithms to model user engagement in long-term, in-home interventions with socially supportive robots is both feasible and effective, opening new avenues for supporting children with ASD. Comparisons between traditional teaching methods and technology-based interventions show that learning robots contribute to greater improvements in educational outcomes. For example, robotic tools used for teaching numerical position led to higher scores than classical teaching methods [41]. Similarly, the use of advanced machine learning algorithms allowed for better prediction of students' attention and improved engagement in the learning process [39]. However, despite the high accuracy of certain models, challenges remain in generalizing results to new data and diverse contexts. For instance, the model by Hadri and Bouramoul (2023) [26], although achieving 98% accuracy on training data, requires further investigation to adapt to new cases and integrate variables such as the learning pace of children with ASD. Additionally, there is a critical need to diversify intervention models to accommodate a wider range of dialogues and social interactions. The integration of AI into intervention strategies emerges as a promising approach, leading to more targeted and personalized therapies that foster learning and social development [43].

Challenges and Ethical Issues

The implementation of technologies such as AI and social robots in the education of children with ASD raises significant concerns regarding the protection of personal data. The analysis of large volumes of data collected from children necessitates stringent data protection policies and the explicit consent of parents, as privacy violations remain a major concern [44; 34; 43; 38] highlight the importance of strict data security protocols to ensure children's safety during such interventions. In parallel, the issues of transparency and algorithmic bias are

particularly critical. The lack of transparency in AI systems may lead to inequalities or inherent biases, potentially undermining the reliability and fairness of the outcomes. To mitigate these risks, Barua et al. (2022) [38; 44; 45] and Adako et al., 2024b ; Adako et al., 2024a [44; 45] emphasize the necessity of cultural diversity and cross-sectoral collaboration in the development of more reliable and equitable systems. Another key issue involves the potential replacement of the human element with technology. The growing dependence on robots and AI systems may reduce opportunities for authentic human interaction, raising concerns about a lack of empathy and emotional understanding from technological tools [34; 31; 46]. Barua et al. (2022) point to the risks associated with forming dependent relationships on technology and the possibility that these systems might gradually supplant meaningful human connections and interaction. Furthermore, technological and financial constraints significantly impact the widespread implementation of these technologies. Budget limitations and the high cost of such tools pose considerable challenges, particularly in under-resourced educational settings [46]. Additionally, the lack of teacher training and the pressing need to develop ethical frameworks for fair and inclusive technology use are equally important concerns [46; 38; 31]. These issues highlight the urgent need for strategic planning to ensure equitable access and ethical integration of new technologies, despite existing limitations. Overall, while technology holds great promise for enhancing the education of children with ASD, rigorous policies and a thoughtful examination of the ethical, social, and economic dimensions are essential to ensure its effective and safe implementation [44]. The key ethical, social, and practical challenges associated with the use of AI and social robotics in ASD education are summarized in Table 3.

Table3. Ethical, Social, and Practical Challenges associated with the use of AI and social robotics in ASD education

Ethical Challenges and Critical Issues	Description	Sources
Data Privacy Protection	The collection and analysis of large volumes of data from children with ASD poses risks of privacy breaches. Emphasizes the need for parental consent and strict data protection policies.	Barua et al., 2022; Iannone & Giansanti, 2023; Adako et al., 2024a; Wankhede et al., 2024
Algorithmic Transparency and Fairness	Lack of transparency in AI system operations may lead to biased outcomes. Highlights the necessity for cultural diversity and collaboration among stakeholders to ensure fairness.	Barua et al., 2022; Adako et al., 2024a; Adako et al., 2024b
Replacement of Human Interaction – Autonomy	Concerns about reduced human interaction and the development of dependency on robots. Technology lacks empathy, raising questions about emotional development.	Barua et al., 2022; Iannone & Giansanti, 2023; Alabdulkareem et al., 2022; Silvera-Tawil et al., 2022; Adako et al., 2024a
Technological and Economic Constraints	Limited accessibility due to high costs and socio-economic disparities. Highlights the lack of teacher training	Barua et al., 2022; Alabdulkareem et al., 2022; Silvera-Tawil et al., 2022;

	and the need for ethical guidelines to ensure equitable implementation.	Adako et al., 2024; Capraro et al., 2024a
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D. Discussion

The present study aimed to provide a comprehensive literature review on the use of AI and robotics technologies in supporting children with ASD, focusing on their effectiveness in enhancing social and cognitive skills. Within the scope of the review, the tools and methods employed for the implementation of these technologies were analyzed, along with their potential to improve communication, social interaction, and cognitive capabilities in children with ASD [48; 49]. A systematic investigation of AI and robotic tools is essential, as findings indicate that their application offers new possibilities for personalized education and improved social engagement [50]. The continuous advancement in these fields may contribute to the development of innovative intervention strategies that provide more tailored and effective solutions for children with ASD. The significance of such a systematic approach is further supported by the need to understand how technology interacts with the individual needs of these children and how such tools can be applied in real-world educational and therapeutic settings [51].

This review contributes to the scientific community by gathering and analyzing existing AI-and robotics-based tools aimed at promoting social and cognitive skills in children with ASD [52]. Through a systematic examination of their effectiveness, the study highlights the benefits and challenges associated with their use, providing a holistic overview of the current state of knowledge. Moreover, the analysis of ethical and deontological issues emerging from their implementation enriches the ongoing dialogue concerning the safe and responsible integration of these technologies into educational and therapeutic practices. Notably, the review reveals significant progress in the integration of AI and robotics in the education of children with ASD. The increasing use of such technologies has contributed to the support of children's social development, particularly in areas where they commonly experience difficulties, such as emotion recognition and expression, eye contact, and verbal interaction. Technological tools such as chatbots, social robots, IoT applications, and smart environments appear promising in providing children with safe, repetitive opportunities to practice these skills [48; 49]. Emotion recognition and interpretation represent fundamental social competencies, which often present significant challenges for children with ASD. Systems such as the social robot Kaspar have been shown to effectively enhance this skill by offering a non-threatening mode of interaction. According to Bekele et al. (2014) [48], the use of Kaspar led to statistically significant improvements in the recognition of basic facial expressions (e.g., happiness, sadness, and anger), allowing children to practice these skills repetitively and predictably, without the uncertainty of human behavior.

The integration of AI technologies, particularly affective computing, has opened new pathways for intervention in this domain. Applications capable of collecting, analyzing, and responding to facial expressions, vocal tone, and physiological signals are now available. Social robots and virtual agents can detect core emotions (e.g., joy, sadness, anger, fear) in real time and offer adaptive feedback and interactions that enhance emotional awareness and regulation [49]. These tools also recognize social cues and adjust their communication to align with each child's individual needs and situational context [50]. Social robots have demonstrated overall effectiveness in teaching social skills such as eye contact and interpersonal interaction. Studies suggest that the use of humanoid robots and the repeated practice of social scenarios within safe, controlled environments reduce social anxiety and encourage children to engage more

actively in social interactions, take initiative, and exhibit spontaneous communicative behavior [51]. In addition to verbal communication, social robots provide rich examples of non-verbal cues such as gestures, posture, and gaze which are crucial for social understanding. In Pennisi et al. (2016) [52], children who participated in interventions using the NAO robot showed greater initiative in social contact and were more willing to engage in conversations with peers in natural settings after the intervention period. Moreover, emotion recognition technologies based on machine learning algorithms offer personalized learning experiences that target each child's specific challenges [53]. For example, social robots can "train" children to distinguish emotions through mimicking games and positive feedback, fostering emotional empathy and self-awareness—critical components of successful social integration [50]. The evaluation of the effectiveness of AI and Robotic technologies in enhancing the social and cognitive skills of children with ASD constitutes a fundamental issue in educational research and special education. Understanding how these tools support children in their daily lives and educational contexts is critical for the development of more effective intervention strategies. As such, the study of the outcomes associated with these technologies highlights their potential to offer personalized, repetitive, and interactive learning experiences [54]. Clinically validated evidence of their effectiveness is essential not only for the verification of technological solutions but also for their safe integration into educational systems and special education practices. The question of effectiveness goes beyond technical functionality and encompasses the extent to which these technologies provide meaningful support to students and are integrated into everyday pedagogical practices. Existing findings indicate that the use of these tools reduces social anxiety, enhances participation, and enables children to practice social skills in controlled environments, where they can experiment without the fear of rejection [52].

Unlike traditional intervention methods that often rely on continuous interaction with specialized professionals, technology-based approaches allow children to learn within safe, adaptive environments. These environments reduce social fear and anxiety, often experienced in conventional social situations. Furthermore, these innovative technologies provide advantages such as personalization, consistency in instruction, and high interactivity, which increases children's engagement. They can also be deployed at home, offering ongoing support outside the school context. Their interactive nature makes them particularly attractive to children who may not respond well to traditional methods [54]. However, despite their many advantages, it is important to acknowledge that technological interventions cannot replace human interaction. Many studies and applications focused on the development of social skills through screen-based or robotic interventions exhibit limited ability to generalize results to real-world scenarios. This limitation often stems from the lack of large-scale evaluations and the challenges associated with implementing such tools in natural school settings. Most existing research is conducted under laboratory conditions or in small-scale experimental frameworks, which restricts the generalizability of findings [52]. A significant area requiring further investigation concerns the long-term impact of these technological interventions. Most studies assess short-term outcomes without examining whether the social or cognitive skills acquired are maintained over time. This raises questions about the sustainability and durability of the positive effects observed and whether skills acquired through these technologies can be transferred to other contexts [53]. Another key issue relates to the inherent heterogeneity of children with ASD, making individualized approaches critical. Each child presents distinct needs—ranging from cognitive to sensory processing—which are difficult to address through standardized technological solutions. Although adaptive AI platforms show promise in addressing this diversity, their implementation in real educational environments remains at an

early stage [49]. Additionally, the lack of standardized tools for assessing the effectiveness of these technologies presents a major barrier to drawing definitive conclusions. Variability in research protocols, evaluation methods, and participant profiles complicates the objective comparison of outcomes across different technological interventions [48]. In conclusion, while AI and robotics technologies show promising potential in supporting the development of social and cognitive skills in children with ASD, comprehensive and conclusive documentation of their effectiveness requires further systematic research, long-term evaluation, and application in authentic educational settings. The integration of technology into educational settings raises significant ethical and deontological concerns. First and foremost, the protection of personal data is a critical issue, particularly in the context of collecting and analyzing data related to children's behaviors. Such practices must be conducted with full transparency and informed parental consent, in strict compliance with the General Data Protection Regulation (GDPR) (2016) [62]. Algorithmic bias also presents a major concern, as algorithms may inadvertently reinforce existing social inequalities, thereby negatively impacting children from disadvantaged backgrounds [55]. Moreover, an overreliance on technological tools may reduce opportunities for human interaction, which is vital for the development of children's social and emotional skills. The continuous use of AI and robotics for teaching and interaction has the potential to undermine the development of empathy and emotional regulation [56]. For instance, AI-driven robots have been found to unintentionally embed and replicate harmful stereotypes—such as racial or gender biases adversely affecting children's social value systems [55]. Human guidance remains irreplaceable, as technology cannot substitute the essential social competencies cultivated through relationships with teachers and peers [57]. The use of technology in education should serve to enhance, not replace, human relationships, ensuring that students continue to develop autonomy, empathy, and critical thinking skills [58; 59; 60]. These considerations underscore the importance of implementing educational technologies responsibly and ethically. Safeguarding personal data, avoiding algorithmic bias, and fostering cooperation between technological tools and human elements are essential to maintaining a balanced and inclusive educational experience.

This study presents several limitations that must be considered when interpreting its findings. First, the effectiveness of AI and robotic tools in fostering social and cognitive skills among children with ASD remains inconclusive. Many of the studies reviewed are still in pilot phases or exhibit methodological heterogeneity and inconsistent evaluation criteria, which challenges the synthesis of definitive outcomes. Furthermore, the review was limited to a relatively small number of studies, primarily due to the scarcity of research in this field and the stringent inclusion criteria applied. This limitation may affect the comprehensiveness and representativeness of the conclusions drawn. Finally, the generalizability of the findings is constrained by the nature of the available data, as most studies are based on small sample sizes or are situated within specific sociocultural contexts. As a result, broader and more universally applicable conclusions remain difficult to establish.

References

- [1] American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders. *Diagnostic and Statistical Manual of Mental Disorders*. <https://doi.org/10.1176/APPI.BOOKS.9780890425596>, 2013.
- [2] World Health Organization. Autism spectrum disorder, 2023. <https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders>

- [3] C. Lord, M. Elsabbagh, G. Baird, G., & J. Veenstra-Vanderweele: Autism spectrum disorder. In *The Lancet* (Vol. 392, pp. 508–520). Lancet Publishing Group. [https://doi.org/10.1016/S0140-6736\(18\)31129-2](https://doi.org/10.1016/S0140-6736(18)31129-2), 2018.
- [4] American Psychiatric Association: *DIAGNOSTIC AND STATISTICAL MANUAL OF DSM-5 TM.*, 2012.
- [5] C. Lord, T.S. Brugha, T. Charman, J. Cusack, G. Dumas, T. Frazier, E. J. H. Jones, R. M. Jones, A. Pickles, M.W. State, J.L. Taylor, & J. Veenstra-VanderWeele: *Nature Reviews Disease Primers*, 6. <https://doi.org/10.1038/s41572-019-0138-4>, 2020.
- [6] A. Klin, C. A. Saulnier, S.S. Sparrow, D.V. Cicchetti, F.R. Volkmar, & C. Lord: Social and communication abilities and disabilities in higher functioning individuals with autism spectrum disorders: The Vineland and the ADOS. *Journal of Autism and Developmental Disorders*, 37, 748–759. <https://doi.org/10.1007/s10803-006-0229-4>, 2007.
- [7] J.L. Matson, N.C. Turygin, J. Beighley, R. Rieske, K. Tureck, & M.L. Matson: Applied behavior analysis in Autism Spectrum Disorders: Recent developments, strengths, and pitfalls. *Research in Autism Spectrum Disorders*, 6, 144–150. <https://doi.org/10.1016/j.rasd.2011.03.014>, 2012.
- [8] Q. Yu, E. Li, L. Li, L., & W. Liang: Efficacy of interventions based on applied behavior analysis for autism spectrum disorder: A meta-analysis. *Psychiatry Investigation*, 17, 432–443. <https://doi.org/10.30773/pi.2019.0229>, 2020.
- [9] Y. Purnama, F.A. Herman, J. Hartono, D. Neilsen, Suryani, & G. Sanjaya: Educational Software as Assistive Technologies for Children with Autism Spectrum Disorder. *Procedia Computer Science*, 179, 6–16. <https://doi.org/10.1016/j.procs.2020.12.002>, 2021.
- [10] Ongsulee, P. *Artificial Intelligence, Machine Learning and Deep Learning*. <https://ieeexplore.ieee.org/stampPDF/getPDF.jsp?tp=&arnumber=8259629&ref=>, 2017.
- [11] B. Mahesh: Machine Learning Algorithms - A Review. *International Journal of Science and Research (IJSR)*, 9, 381–386. <https://doi.org/10.21275/art20203995>, 2020.
- [12] F.M. Bianchi, E. Maiorino, M.C. Kampffmeyer, A. Rizzi, & R. Jenssen: *An overview and comparative analysis of Recurrent Neural Networks for Short Term Load Forecasting*. <https://doi.org/10.1007/978-3-319-70338-1>, 2017.
- [13] M.R. Minar, J. & Naher: *Recent Advances in Deep Learning: An Overview*. <https://doi.org/10.13140/RG.2.2.24831.10403>, 2018.
- [14] Micheni, E., Machii, J., & Murumba, J. The Role of Artificial Intelligence in Education. *Open Journal for Information Technology*, 7, 43–54. <https://doi.org/10.32591/coas.ojit.0701.04043m>, 2024.
- [15] Huang, J., Saleh, S., & Liu, Y. A review on artificial intelligence in education. *Academic Journal of Interdisciplinary Studies*, 10, 206–217. <https://doi.org/10.36941/AJIS-2021-0077>, 2021.
- [16] Chen, L., Chen, P., & Lin, Z. Artificial Intelligence in Education: A Review. *IEEE Access*, 8, 75264–75278. <https://doi.org/10.1109/ACCESS.2020.2988510>, 2020.
- [17] Rusmiyanto, R., Huriati, N., Fitriani, N., Tyas, N. K., Rofi'i, A., & Sari, M. N. The Role Of Artificial Intelligence (AI) In Developing English Language Learner's Communication Skills. *Journal on Education*, 6, 750–757. <https://doi.org/10.31004/joe.v6i1.2990>, 2023.
- [18] Rouhi, A., Spitale, M., Catania, F., Cosentino, G., Gelsomini, M., & Garzotto, F. Emotify: Emotional game for children with autism spectrum disorder based-on machine learning. *International Conference on Intelligent User Interfaces, Proceedings IUI*, 31–32. <https://doi.org/10.1145/3308557.3308688>, 2019.

- [19] K. Dautenhahn, A. Bond, L. Cañamero, & B. Edmonds: *Socially Intelligent Agents* (pp. 1–20). https://doi.org/10.1007/0-306-47373-9_1, 2002.
- [20] C. Veronesi, B. Trimarco, N. Botticelli, G. Armani, A. Bentenuto, F. Fioriello, . Picchiotti, & C. Sogos: Use of the PARO robot as a social mediator in a sample of children with neurodevelopmental disorders and typical development. *Clinica Terapeutica*, 174, 132–138. <https://doi.org/10.7417/CT.2023.2509>, 2023.
- [21] T. Hughes-Roberts, V. Cui, M. Mahmud & D. .J. Brown: Leveraging Virtual Reality and Machine Learning as Mediated Learning Tools for Social Skill Development in Learners with Autism Spectrum Condition. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13309 LNCS, 231–240. https://doi.org/10.1007/978-3-031-05039-8_16, 2022a.
- [22] L.J. Wood, A. Zaraki, B. Robins, & K. Dautenhahn: Developing Kaspar: A Humanoid Robot for Children with Autism. *International Journal of Social Robotics*, 13, 491–508. <https://doi.org/10.1007/s12369-019-00563-6>, 2021.
- [23] A. Frolli, A. Cavallaro, I. Penna, S.L. La, Sica, & D. Bloisi: *Artificial intelligence and autism spectrum disorders: a new perspective on learning*, 2023.
- [24] M.R. Ali, S.Z. Razavi, R. Langevin, A. Al Mamun, B. Kane, R. Rawassizadeh, L. K. Schubert, & E.A. Hoque: Virtual Conversational Agent for Teens with Autism Spectrum Disorder: Experimental Results and Design Lessons. *Proceedings of the 20th ACM International Conference on Intelligent Virtual Agents, IVA 2020*. <https://doi.org/10.1145/3383652.3423900>, 2020.
- [25] W. Farzana, F. Sarker, T. Chau, & K.A. Mamun: Technological Evolvement in AAC Modalities to Foster Communications of Verbally Challenged ASD Children: A Systematic Review. *IEEE Access*. <https://doi.org/10.1109/ACCESS.2021.3055195>, 2021.
- [26] S.A. Hadri, & A. Bouramoul: Towards a deep learning based contextual chat bot for preventing depression in young children with autistic spectrum disorder. *Smart Health*, 27, 100371. <https://doi.org/10.1016/J.SMHL.2022.100371>, 2023.
- [27] L. Xuan, Z. Jiaming, Z.Huixin & Z. Bin: A General Chinese Chatbot Based on Deep Learning and Its' Application for Children with ASD. *International Journal of Machine Learning and Computing*. <https://doi.org/10.18178/ijmlc.2020.10.4.967>, 2020.
- [28] U. Qidwai, S.B.A. Kashem, & O. Conor: Humanoid Robot as a Teacher's Assistant: Helping Children with Autism to Learn Social and Academic Skills. *Journal of Intelligent and Robotic Systems: Theory and Applications*, 98, 759–770. <https://doi.org/10.1007/s10846-019-01075-1>, 2020.
- [29] S.K. Kim, M. Hirokawa, S. Matsuda, A. Funahashi, & K. Suzuki: Smiles as a Signal of Prosocial Behaviors Toward the Robot in the Therapeutic Setting for Children With Autism Spectrum Disorder. *Frontiers in Robotics and AI*, 8. <https://doi.org/10.3389/frobt.2021.599755>, 2021.
- [30] D. Ghiglino, P. Chevalier, F. Floris, T. Priolo, & A. Wykowska: Follow the white robot: Efficacy of robot-assistive training for children with autism spectrum disorder. *Research in Autism Spectrum Disorders*, 86. <https://doi.org/10.1016/j.rasd.2021.101822>, 2021.
- [31] A. Alabdulkareem, N. Alhakbani, A.A. & Al-Nafjan: Systematic Review of Research on Robot-Assisted Therapy for Children with Autism. In *Sensors* (Vol. 22). MDPI. <https://doi.org/10.3390/s22030944>, 2021.
- [32] F. Bertacchini, F. Demarco, C. Scuro, P. Pantano, & E. Bilotta: A social robot connected with chatGPT to improve cognitive functioning in ASD subjects. *Frontiers in Psychology*, 14. <https://doi.org/10.3389/fpsyg.2023.1232177>, 2023.

- [33] G. Wan, F. Deng, Z. Jiang, S. Song, D. Hu, L. Chen, H. Wang, M. Li, G. Chen, T. Yan, J. Su, & J. Zhang: FECTS: A Facial Emotion Cognition and Training System for Chinese Children with Autism Spectrum Disorder. *Computational Intelligence and Neuroscience*, 2022. <https://doi.org/10.1155/2022/9213526>, 2022.
- [34] A. Iannone, & D. Giansanti: Breaking Barriers-The Intersection of AI and Assistive Technology in Autism Care: A Narrative Review. *Journal of Personalized Medicine*, 14(1). <https://doi.org/10.3390/JPM14010041>, 2023.
- [35] F. Ullah, N.A. AbuAli, A. Ullah, R. Ullah, U.A. Siddiqui, A. A., & Siddiqui: Fusion-Based Body-Worn IoT Sensor Platform for Gesture Recognition of Autism Spectrum Disorder Children. *Sensors*, 23. <https://doi.org/10.3390/s23031672>, 2023.
- [36] M. Abdel Hameed, M. Hassaballah, M.E. Hosney, A. & Alqahtani: An AI-Enabled Internet of Things Based Autism Care System for Improving Cognitive Ability of Children with Autism Spectrum Disorders. *Computational Intelligence and Neuroscience*, 2022. <https://doi.org/10.1155/2022/2247675>, 2022.
- [37] O. Adako, O. Adeusi, & P. Alaba: Integrating AI tools for enhanced autism education: a comprehensive review. In *International Journal of Developmental Disabilities*. Taylor and Francis Ltd. <https://doi.org/10.1080/20473869.2024.2392983>, 2024.
- [38] P.D. Barua, J. Vicnesh, R. Gururajan, S.L. Oh, E. Palmer, M.M. Azizan, N.A. Kadri, & U.R. Acharya: Artificial Intelligence Enabled Personalised Assistive Tools to Enhance Education of Children with Neurodevelopmental Disorders—A Review. In *International Journal of Environmental Research and Public Health* (Vol. 19). MDPI. <https://doi.org/10.3390/ijerph19031192>, 2022.
- [39] L. Deng, & P. Rattadilok: A Sensor and Machine Learning-Based Sensory Management Recommendation System for Children with Autism Spectrum Disorders. *Sensors*, 22. <https://doi.org/10.3390/s22155803>, 2022.
- [40] K. Nguyen, & Y. Huang: Applying Artificial Intelligence in Diagnosis and Treatment of Autism Spectrum Disorder in Children. *Journal of Student Research*, 13. <https://doi.org/10.47611/jsrhs.v13i2.6803>, 2024
- [41] N.I. Arshad, A.S. Hashim, M. Mohd Ariffin, N. Mohd Aszemi, h.m. Low, & A. A. Norman: Robots as Assistive Technology Tools to Enhance Cognitive Abilities and Foster Valuable Learning Experiences among Young Children with Autism Spectrum Disorder. *IEEE Access*, 8, 116279–116291. <https://doi.org/10.1109/ACCESS.2020.3001629>, 2020.
- [42] S. Jain, B. Thiagarajan, Z. Shi, C. Clabaugh, & M. J. Matarić: Modeling engagement in long-term, in-home socially assistive robot interventions for children with autism spectrum disorders. *Science Robotics*, 5. <https://doi.org/10.1126/scirobotics.aaz3791>, 2020.
- [43] N. Wankhede, M. Kale, M. Shukla, D.R.R. Nathiya, P. Kaur, B. Goyanka, S. Rahangdale, B. Taksande, A. Upaganlawar, M. Khalid, S. Chigurupati, M. Umekar, S.R. Kopalli, & S. Koppula: Leveraging AI for the diagnosis and treatment of autism spectrum disorder: Current trends and future prospects. *Asian Journal of Psychiatry*, 101, 104241. <https://doi.org/10.1016/J.AJP.2024.104241>, 2024.
- [44] O.P. Adako, O. C. Adeusi, & P.A. Alaba: Enhancing Educational Inclusivity for Autistic Children: The Imperative of Individualization and Personalization in AI Tools. *Journal of Neurology and Neurological Disorder*, 10(2), 201. www.annepublishers.com, 2024a.
- [45] O. Adako, O. Adeusi, & P. Alaba: Integrating AI tools for enhanced autism education: a comprehensive review. In *International Journal of Developmental Disabilities*. Taylor and Francis Ltd. <https://doi.org/10.1080/20473869.2024.2392983>, 2024.

- [46] D. Silvera-Tawil, S. Bruck, Y. Xiao, & D. K. Bradford: Socially-Assistive Robots to Support Learning in Students on the Autism Spectrum: Investigating Educator Perspectives and a Pilot Trial of a Mobile Platform to Remove Barriers to Implementation. *Sensors*, 22. <https://doi.org/10.3390/s22166125>, 2022.
- [47] V. Capraro, A. Lentsch, D. Acemoglu, S. Akgun, A. Akhmedova, E. Bilancini, J-F Bonnefon, P. Brañas-Garza, L. Butera, K.M. Douglas, J.A.C. Everett, G. Gigerenzer, C. Greenhow, D.A. Hashimoto, J. Holt-Lunstad, J. Jetten, S. Johnson, W.H. Kunz, C. Longoni, ... R. Viale: The impact of generative artificial intelligence on socioeconomic inequalities and policy making. *PNAS Nexus*, 3, pgae191. <https://doi.org/10.1093/pnasnexus/pgae191>, 2024.
- [48] E. Bekele, J.A. Crittendon, A., Swanson, N. Sarkar, & Z. E. Warren: Pilot clinical application of an adaptive robotic system for young children with autism. *Autism*, 18, 598–608. <https://doi.org/10.1177/1362361313479454>, 2014.
- [49] S. Cano, C.S. González, R.M. Gil-Iranzo, & S. Albiol-Pérez: Affective communication for socially assistive robots (SARs) for children with autism spectrum disorder: A systematic review. *Sensors*, 21. <https://doi.org/10.3390/s21155166>, 2021.
- [50] F. Perillo, F., M. Romano, & G. Vitiello: *Social Robots Design to improve Social Skills in Autism Spectrum Disorder*, 2024.
- [51] S. Doğan, & A. Çolak: Social robots in the instruction of social skills in autism: a comprehensive descriptive analysis of single-case experimental designs. In *Disability and Rehabilitation: Assistive Technology* (Vol. 19, pp. 325–344). Taylor and Francis Ltd. <https://doi.org/10.1080/17483107.2022.2087772>, 2024.
- [52] P. Pennisi, A. Tonacci, G. Tartarisco, L. Billeci, L. Ruta, S. Gangemi, & G. Pioggia: Autism and social robotics: A systematic review. In *Autism Research* (Vol. 9, pp. 165–183). John Wiley and Sons Inc. <https://doi.org/10.1002/aur.1527>, 2016.
- [53] P.W.S. Leung, S.X. Li, C.S.O. Tsang, B.L.S. Chow, & W.C.W. Wong: Effectiveness of Using Mobile Technology to Improve Cognitive and Social Skills Among Individuals With Autism Spectrum Disorder: Systematic Literature Review. *JMIR Mental Health*, 8, e20892. <https://doi.org/10.2196/20892>, 2021.
- [54] G. Thunberg, E. Ahlsén, & A.D. Sandberg: Autism, communication and use of a speech-generating device in different environments - a case study. *Journal of Assistive Technologies*, 5, 181–198. <https://doi.org/10.1108/17549451111190605>, 2011.
- [55] O. Boateng, & B. Boateng: Algorithmic bias in educational systems: Examining the impact of AI-driven decision making in modern education. *World Journal of Advanced Research and Reviews*, 25, 2012–2017. <https://doi.org/10.30574/wjarr.2025.25.1.0253>, 2025.
- [56] L. Krstić, V. Aleksić, & M. Krstić.: *Artificial Intelligence in Education: A Review*. 223–228. <https://doi.org/10.46793/tie22.223k>, 2022.
- [57] C.V. Felix: *The Role of the Teacher and AI in Education* (pp. 33–48). <https://doi.org/10.1108/s2055-364120200000033003>, 2020.
- [58] I. Levin, M. Marom, & A. Kojukhov: Rethinking AI in Education: Highlighting the Metacognitive Challenge. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, 16, 250. <https://doi.org/10.70594/brain/16.S1/21>, 2025.
- [59] T. Hughes-Roberts, V. Cui, M. Mahmud, & D.J. Brown: Leveraging Virtual Reality and Machine Learning as Mediated Learning Tools for Social Skill Development in Learners with Autism Spectrum Condition. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13309 LNCS, 231–240. https://doi.org/10.1007/978-3-031-05039-8_16 (2022b).

- [60] C.A.G.J. Huijnen, M.A.S. Lexis, R. Jansens, & L. P. de Witte: Roles, Strengths and Challenges of Using Robots in Interventions for Children with Autism Spectrum Disorder (ASD). *Journal of Autism and Developmental Disorders*, 49, 11–21. <https://doi.org/10.1007/s10803-018-3683-x>, 2019.
- [61] *PRISMA statement*. <https://www.prisma-statement.org/prisma-2020-flow-diagram>, 2020.
- [62] *General Data Protection Regulation (GDPR) – Legal Text*. <https://gdpr-info.eu/>, 2016.