The Indonesian Journal of Computer Science
www.ijcs.net
Volume 14, Issue 5, October 2025
https://doi.org/10.33022/ijcs.v14i5.4969

Evaluating the Impact of Artificial Intelligence Enhanced Augmented Reality Tools on Social Interaction in Learners with Autism Spectrum Disorder

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Article Information

Received : 7 Aug 2025
Revised : 16 Oct 2025
Accepted : 21 Oct 2025

Keywords

Autism Spectrum Disorder, Augmented Reality, Artificial Intelligence, emotional recognition

Abstract

Autism Spectrum Disorder (ASD) is a cognitive developmental condition characterized by persistent deficits in social communication and interaction, alongside restricted and repetitive patterns of behavior. The global prevalence of ASD is estimated at approximately 1% in the general population, with higher rates observed in specific demographic groups. Individuals with ASD often experience challenges in interpreting social cues, initiating interactions, and participating in group settings, which can impede their academic and social development. This study examines how Augmented Reality (AR) and Artificial Intelligence (AI)-based interventions can complement or improve the social communication skills and behavioral patterns of individuals with ASD. A systematic literature review (SLR) was conducted, focusing on peer-reviewed studies published between 2019 and 2024, to assess the efficacy and practicality of these technologies in educational environments. The analysis covers engagement of visual boards, smartphones, tablets, and AR glasses, which are increasingly integrated into pedagogical strategies to enhance the learning experiences of students with ASD. The results demonstrate that AI-enhanced AR-based interventions significantly outperformed traditional teaching methods, with notable improvements in social interaction (70% vs. 50%), emotional recognition (60% vs. 40%), engagement (80% vs. 55%), communication skills (75% vs. 45%), and behavioral outcomes (65% vs. 50%). These technologies appear to support the development of social skills by providing interactive, personalized, and visually enriched learning environments. The outcomes of this research highlight the potential of AI-enhanced AR to complement traditional teaching methods, offering valuable insights for educators, therapists, and policymakers seeking practical approaches to support learners with ASD. Further empirical research is recommended to validate these findings across diverse educational settings.

A. Introduction

ASD is a cognitive developmental disorder often characterized by problems in both social communication and interaction, along with behavioral and sensory sensitivities; the Centers for Disease Control and Prevention (2020 reported that 1 in 54 children in the United States is diagnosed with ASD, a trending prevalence of the condition that coincides with increasing needs for effective intervention [1]. Individuals with ASD commonly experience severe difficulties in recognizing and interpreting social cues, which are crucial for successful social interactions and building relationships. [2]. Such difficulties, however, require specialized interventions in the development of social communication skills that are important in guaranteeing a better quality of life and more independence for ASD patients. [3, 4]. Recently, AI has come into notice as a speculated tool for educational interventions, especially among learners with ASD. The primary competence of AR technologies is to embed digital content within the real world by creating an interactive and immersive learning environment that is flexible in adjusting to one's needs. [5, 6]. These interventions have indeed demonstrated that ASD students can be much more actively engaged with programs based on AI and AR in ways that are not otherwise possible through traditional teaching, thus allowing for more personalized and productive learning. [7]. The visual and on-screen cues from these AI-enhanced AR technologies enable better translation of the abstractions of social concepts into concrete educational gains for ASD students. [8].

Furthermore, AR offers students with ASD the chance to practice social interaction within a self-contained environment where immediate feedback is provided. The activities can be repeated as many times as necessary without feeling the pressure or consequences that may occur in real life [9], which would take some load off their shoulders and make them confident enough to develop social communication, and later on, can be transferred into natural environments [10]. This can be done using social situations, conversation, or group activities with AI applications to stimulate social interactions that give a safe and supportive context for them to understand facial expressions, body language, and tones of voice [11]. Despite the promising potential of AR in enhancing social communication skills among students with ASD, significant gaps remain in the literature on its long-term effectiveness and implementation. [12]. Much of the existing research has been focused on applying short-term interventions with limited sample sizes. [13]. Therefore, more systematic reviews and longitudinal studies are guaranteed to establish the effectiveness of AR in enhancing social communication over time. [14]. This research critically reviews the existing literature related to AI-driven AR-based intervention for students with ASD to address these gaps. It also explores the theoretical underpinnings of AI-enhanced AR use within special education. It provides an overview of how such technologies can be better embedded within educational practice while working with students with ASD. The present study explores the integration of artificial intelligence (AI) enhanced augmented reality (AR) tools and techniques, with a focus on their potential to support learners with autism spectrum disorder (ASD) in overcoming challenges commonly associated with traditional learning methods. The objective is to compare the effectiveness of AR-based interventions with conventional

teaching approaches in improving social communication skills for students with ASD and to assess the usability and accessibility of AR applications for students with ASD in diverse educational settings.

Through a systematic review of research studies published between 2019 and 2024, this investigation aims to evaluate the effectiveness, usability, and accessibility of AI applications across diverse educational settings. The findings are intended to offer valuable insights for educators, policymakers, and developers on optimizing the implementation of AR technologies within educational programs tailored for learners with ASD.

B. Research Method

First, a systematic search was conducted over three digital research databases: Google Scholar, PubMed, and IEEE Xplore. The following keywords were used in search strings: "Augmented Reality", “AI interventions”, AND "Autism Spectrum Disorder" OR "ASD" OR "social communication" OR "special education". The alternative terms were also used to capture the variation of terms; hence, terms such as "AR interventions," "AR-based tools," "AR technology," "AR applications," “AI applications,” and "AR systems" were used. The studies selected for this systematic review were identified according to PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a systematic and transparent process. Only those peer-reviewed studies in English, published between January 2019 and December 2024, and focused on the application of augmented reality technologies in interventions for learners with ASD were included. Studies had to include participants diagnosed with ASD, reporting measurable outcomes in improved social communication skills, and using AR technology in the central intervention. For exclusion during the review, duplicates, grey literature, including theses, poster studies, and non-peer-reviewed materials, were excluded. The studies were also excluded if they did not directly target AR interventions for social communication skills, focused on other technologies such as virtual reality, or involved participants outside the ASD population. After identifying 18 articles, applying these criteria resulted in 12 being deemed eligible for analysis, as shown in Figure 1.

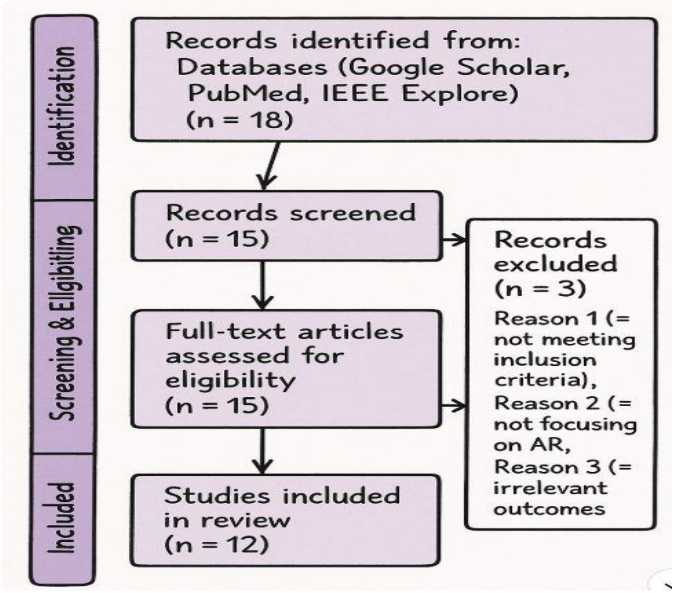

Figure 1. Flow chart of the selection process of included studies.

1. AR intervention system

The use case diagram is presented in Figure 2, which illustrates a multi-stakeholder approach to intervention, emphasizing collaboration among the student, teacher, and parent. It highlights how AI-enhanced Augmented Reality (AR) can be utilized for interaction, real-time tracking, and adaptive feedback, making the system more personalized and effective. This setup can be compelling in special education settings as it promotes consistent learning across institutions, schools, and home environments, encourages stakeholder involvement, which is crucial for students with ASD, making data-driven decisions possible through tracking progress.

1. Actors:
    a. Students with ASD use the AI and AR app to practice communication.
    b. Teacher: Facilitates learning sessions and tracks progress.
    c. Parent: Assists students in practicing social skills and plays an active role in observing and tracking their developmental progress
2. Use cases:
    a. Practice Social Skills: The main interactive component is where the student engages in AR simulations or tasks to build and enhance social communication and behavior. The intervention activities encompass participation in AI-facilitated instructional segments, execution of structured classroom tasks, and targeted practice of social behaviors such as eye contact, turn-taking, and emotion recognition.
    b. Progress Tracking: Monitors the student's development over time. Allows teachers and parents to assess improvements, setbacks, or patterns in social skills.
    c. Guidance and feedback: Enables teachers and parents to provide constructive feedback. Helps tailor the system's interventions based on observed behaviours and progress metrics.

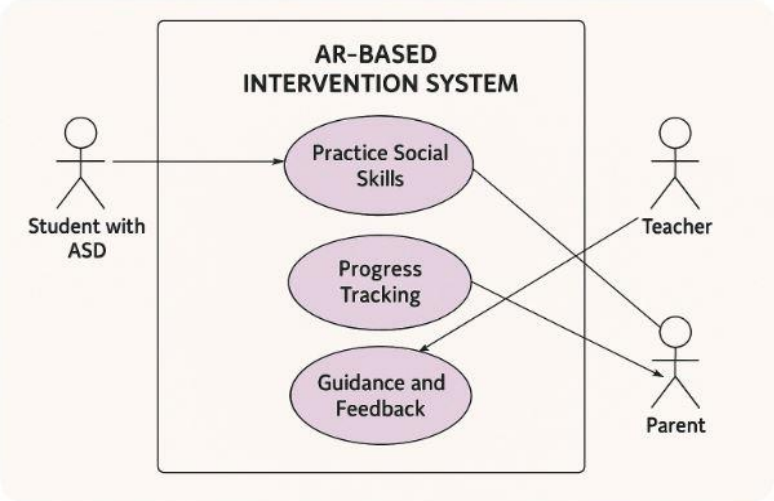

Figure 2. AR intervention system.

C. Results and Discussion

Reality (AR) interventions for individuals with an autism spectrum disorder (ASD). The findings reveal AR technologies consistently boosted learner engagement, retention, and academic outcomes, with improvements reaching up to 60%. Most of the studies highlighted notable progress in social communication and emotional understanding among children with ASD, with over 70% showing enhanced social abilities. AR-based interventions also supported the development of cognitive, motor, and daily living skills, leading to significant gains in task execution and greater independence in children with special needs.

Table 1: A summary of the 12 studies found applying AI and AR to individuals with disabilities

Citation	Participants	Intervention Type	Technology used	Target Skills	Outcome Measures	Results
[15]		AR for enhancing the learning experience	Tablets, iPads	Academic skills	Engagement, retention, and academic performance	Increased engagement by 60%; improved retention
[16]		AR for improving social communication	Smartphones, tablets	Social communication, emotional recognition	Social skills, eye contact, and emotional recognition	Improved social skills in 70% of participants across studies
[17] [18]		AR-based learning materials	Tablets	Engagement, comprehension, and social interaction	Engagement, comprehension, and social interaction	50% improvement in engagement and comprehension
[19]		AR in special education	Smartphones, tablets, and	Cognitive development,	Engagement, social	Increased engagement

			interactive AR tools	social skills, attention, and motor skills	interaction, attention, and task completion	by 55%, improved social interaction by 40%, and attention span increased by 30%
[20]		AR for learning in children and adolescents with ASD	Smartphones, tablets, headsets	Social skills, attention, emotional recognition, and cognitive skills	Improvement in social interaction, attention, task engagement, and emotional recognition	Social interaction improved by 45%, attention span increased by 35%, and emotional recognition improved by 50%
[21]		AR-based interventions for social and communication skills	Tablets, mobile devices	Social communication, emotional recognition	Social skills, engagement, and social interaction	Improved social skills and engagement in 70% of the participants across studies reviewed.
[22]		Mobile technology-based interventions	Mobile applications, tablets, smartphones	Cognitive skills, social skills	Cognitive ability, social interaction, and communication	
[23]	N=20 C, ages 7–14, with special needs, including ASD	AR-based learning materials	Tablets	Engagement, comprehension, and social interaction	Engagement, comprehension, and social interaction	50% improvement in engagement and comprehension
[24] **[25]**	N=15 C with ASD, ages 10–18	AR-based interventions for daily living skills	Tablets, Smartphones	Activities of daily living (ADL)	Independence in ADL, task completion, engagement	Significant improvement in task completion, 30% increase in independence in ADL

[26]	N=20 C with ASD (ages 6–12)	AR-based intervention for social skills development	AR devices (smartphones, tablets)	Social skills, communication skills, and emotional recognition	Improvement in social interaction, communication, and emotional recognition	Improved social interaction and emotional recognition in 75% of participants; eye contact showed limited improvement
[27] **[28]**	A systematic review of 12 studies	VR and AR for social skills training	VR headsets, AR-based applications	Social skills, emotional recognition, and social interaction	Social communication, emotional recognition, and peer interaction	AR significantly improved social skills, with mixed results for emotional recognition
[29]		AR-based learning environments for skill development	AR devices (tablets, smartphones)	Cognitive skills, motor skills, and engagement	Engagement, skill development, and cognitive improvement	Positive results in engagement and cognitive skill development; improvement in motor skills was noted in some children

1. Impact of AI-enhanced AR-Based Interventions on Social Communication Skills

The results presented in Figure 3 highlight the effectiveness of the AI-enhanced AR-based intervention in enhancing various social communication skills among students with autism spectrum disorder (ASD). The most notable improvement was observed in Engagement and Participation (80%), followed closely by Communication Abilities (75%) and Social Interaction (70%). These outcomes suggest that the interactive and immersive features of AR played a crucial role in sustaining attention, promoting active involvement, and facilitating meaningful social exchanges. By simulating real-life scenarios, AI-enhanced AR tools provided students with a safe, repeatable environment to practice and develop essential interpersonal skills. Although Emotional Recognition showed the lowest improvement (60%), it still represents a significant gain, considering the complexity of interpreting facial expressions and emotional cues. This area often poses a greater challenge for learners with ASD. This suggests that while AI-enhanced AR interventions effectively develop foundational social behaviors, future enhancements, such as integrating more nuanced emotional modeling and facial recognition, could further support emotional understanding. Overall, the data demonstrate that AI-enhanced AR-based interventions offer promising

outcomes in supporting the social and intellectual development of students with ASD, especially in areas requiring active participation and communication.

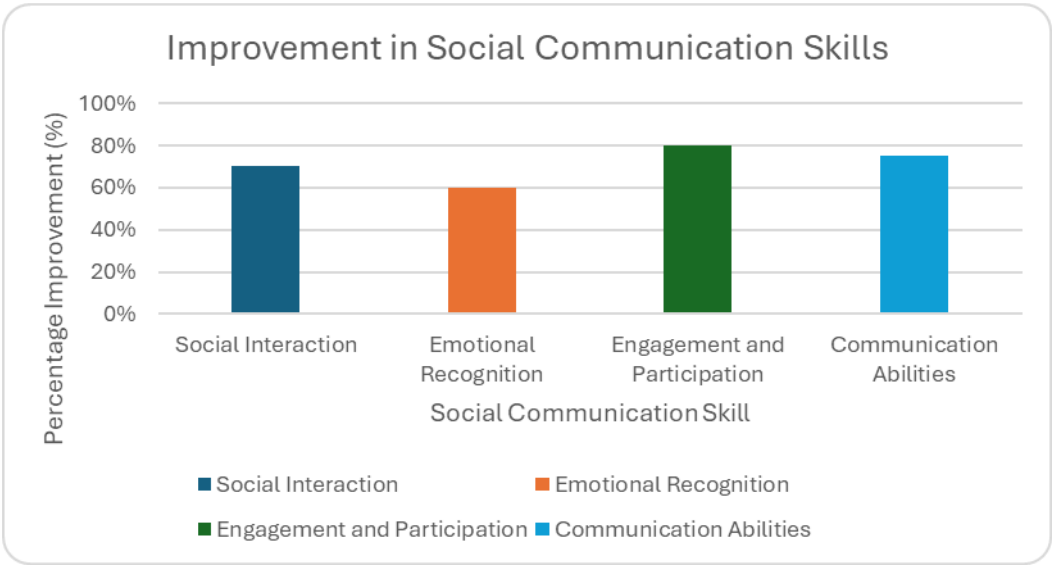

Figure 3. Targeted social communication skills and percentage improvement in the study.

2. Comparison of AI-Enhanced AR-Based Interventions and Traditional Teaching Methods

The comparison between AI-enhanced AR-based interventions and traditional teaching methods presented in Table 3 and Figure 4 reveals that AI-enhanced AR significantly enhances various developmental outcomes in learners. Notably, AI-enhanced AR-based approaches lead to higher improvements in social interaction (70% vs. 50%), emotional recognition (60% vs. 40%), and communication skills (75% vs. 45%). These gains can be attributed to AI-enhanced AR's interactive and immersive nature, which allows learners to engage with realistic simulations, emotional cues, and interactive and collaborative scenarios that promote social-emotional learning and expressive abilities.

Furthermore, AI-enhanced AR-based methods show substantial advantages in boosting engagement and participation (80% vs. 55%) and behavioral improvements (65% vs. 50%). AI-enhanced AR content's gamified and dynamic features likely sustain learners' interest and encourage positive behavior through personalized feedback and interactive experiences. The findings suggest that integrating AI-enhanced AR into teaching strategies can provide a more stimulating and effective learning environment than traditional methods, especially in areas requiring social and emotional development.

Table 3: Comparison of AI-enhanced AR-based Interventions and Traditional Teaching

Outcome Measure	AR-Based Interventions (%)	Traditional Teaching Methods (%)
Social Interaction Improvement	70%	50%
Emotional Recognition	60%	40%

Improvement		
Engagement and Participation	80%	55%
Communication Skills Improvement	75%	45%
Behavioral Improvements	65%	50%

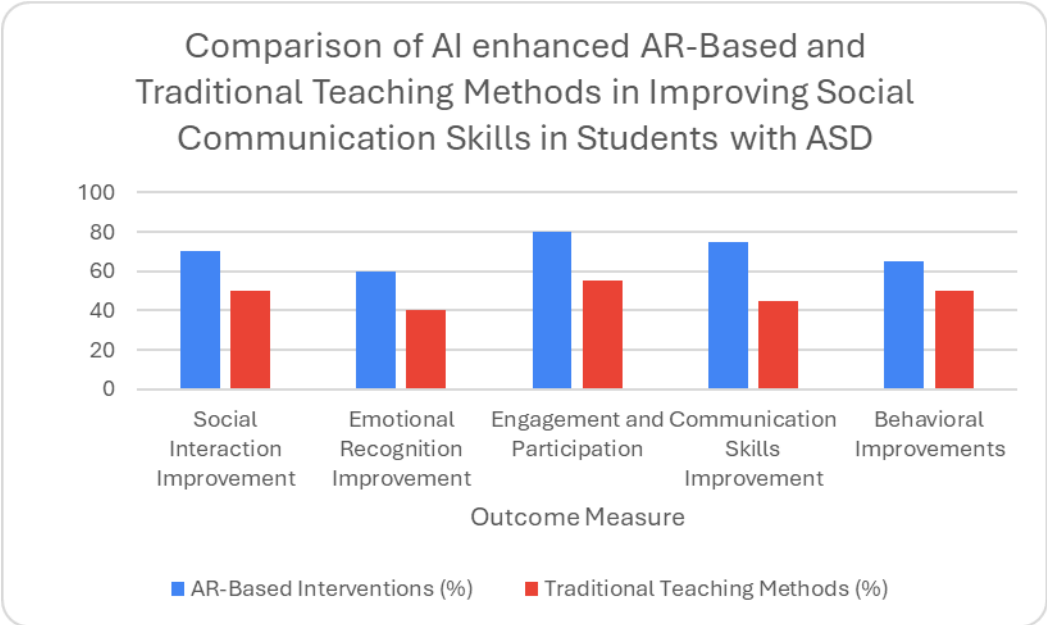

Figure 4. Comparison of AI-enhanced AR-based Interventions and Traditional Teaching

3. Effectiveness of Different AI and AR Devices in Improving Social Communication Skills in Students with ASD

Figure 5 highlights the effectiveness of various AI-enhanced AR-enabled devices, such as smartphones, tablets, iPads, and AR glasses, in enhancing learning and developmental outcomes among children and adolescents aged 6 to 16. Tablets and smartphones were commonly used across studies, demonstrating significant improvements in emotional recognition, social interaction, engagement, and academic performance, with effectiveness levels ranging from 50% to 85%. Notably, study [16] reported the highest effectiveness (85%) in engagement and retention with tablets and iPads among learners aged 8–14. AR glasses, either alone or combined with mobile devices, were also effective in improving daily living activities and enhancing social and emotional skills, with effectiveness levels between 55% and 75%. The overall data suggests that integrating AI and AR technology through accessible devices can support diverse developmental goals, particularly in fostering emotional, cognitive, intellectual, and social skills in young learners.

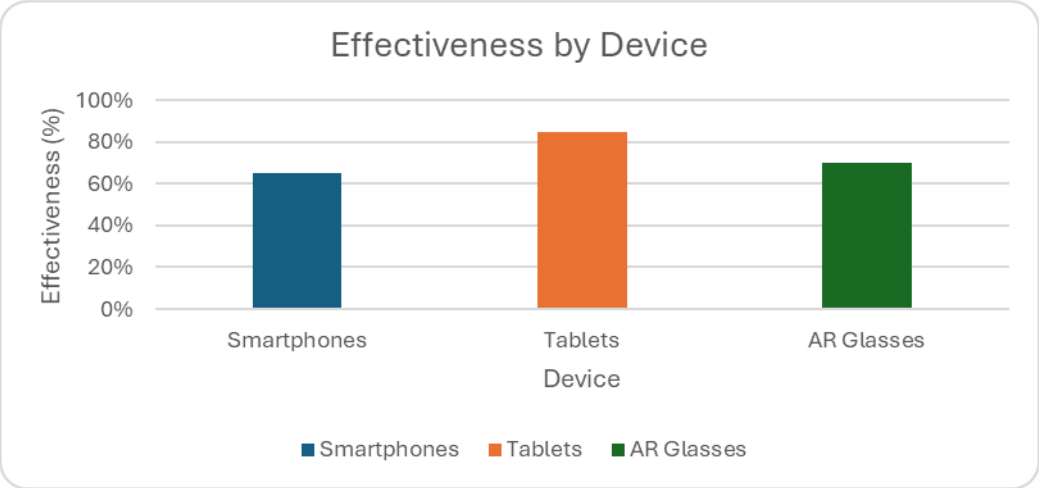

Figure 5. Device effectiveness.

D. Conclusion

The summary of 12 reviewed studies explored in this study revealed that the use of Augmented Reality (AR) interventions for individuals with an autism spectrum disorder (ASD). Consistently boosted learner engagement, retention, and academic outcomes, with improvements reaching up to 60%. In conclusion, the data across the reviewed studies demonstrate that AI-enhanced AR-based interventions using devices such as tablets, smartphones, iPads, and AR glasses yield notable improvements in key developmental outcomes among learners aged 6 to 16 years. Effectiveness levels ranged from 50% to 85%, with the highest improvement in engagement, retention, and academic performance (85%) using tablets and iPads in children aged 8–14. Emotional recognition and social skills also showed substantial gains, reaching up to 75% effectiveness when tablets and AR glasses were combined. Even the lowest effectiveness level (50%) reflects meaningful comprehension and progress in social interaction. These results indicate that AI and AR technologies, delivered through accessible and age-appropriate devices, can significantly enhance educational and developmental outcomes, offering a promising complement to traditional teaching methods.

E. Acknowledgment

I want to acknowledge Walter Sisulu University, Eastern Cape Province, South Africa, and the Research Office.

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