

Analyzing the Potential of Using Social Robots in Autism Classroom Settings

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Abstract: In recent years, social robots have rapidly advanced alongside the progress of artificial intelligence. Countries around the world have been enacting strategic initiatives that combine robotics and artificial intelligence, leading to an increasing exploration of the application of AI technology in the field of education. In the context of autism intervention, social robots have shown promising results in intervention programs and behavior therapy for children with autism. However, there is a lack of research specifically focusing on the use of social robots in autism classroom settings. Therefore, we have synthesized existing studies and proposed the integration of social robots into autism classrooms. Through the collaboration between robots and teachers, as well as the interaction between robots and students, we aim to enhance the attention of children with autism in the classroom and explore new impacts on their classroom performance, knowledge acquisition, and generalization of after-class skills.

1. Introduction

Autism Spectrum Disorder (ASD), also known as autism, is a neurodevelopmental disorder characterized by social communication difficulties, restricted interests or repetitive behaviors. It typically starts in early childhood and lasts throughout life, requiring lifelong support. Recently, the prevalence of ASD has been on the rise, with a global prevalence rate of 1-2%, and a higher incidence in males [1]. According to the Centers for Disease Control and Prevention (CDC), in 2018, approximately 1 in 44 children aged 8 in the United States had ASD. The prevalence rate of ASD among children in China is approximately 0.7%, making it the most common type of developmental disability [2]. Currently, the diagnosis of ASD is primarily based on behavioral symptoms, and individuals with ASD share two core features regardless of cultural, ethnic, or socioeconomic backgrounds: social interaction difficulties and repetitive behaviors, interests, and activities [3]. In recent years, the number and proportion of children with ASD in special education in China have been rapidly increasing, attracting widespread attention and placing significant pressure on schools and educational practices [4]. Developing the potential of children and adolescents with ASD and cultivating their social adaptation skills require theoretical and practical research exploration. The application of robotics technology has brought convenience and hope to the rehabilitation of children with ASD. Due to their specific difficulties in facial recognition, children with ASD often pay more attention to non-living objects in their surroundings [5]. Therefore, combining social robots with

the school curriculum for children with ASD is an exploratory approach that can transform learning formats, enrich teaching content, and improve interaction methods.

2. Related works

With the continuous development of artificial intelligence technology, social robots have become an important avenue for enhancing students' abilities and competencies. According to research conducted in international authoritative literature databases, countries with high citation counts in the field of social robot research include the United States, Switzerland, Italy, Japan, and the United Kingdom, with a focus on robot education, language education, and special education [6]. The introduction of social robots has increased students' interest in STEAM-themed courses and has become an important tool and means for interdisciplinary and human-robot collaborative education. It holds significant importance for cultivating students' higher-order abilities such as problem-solving, metacognition, computational thinking, systems thinking, and innovation.

2.1 The application of social robots in typical children groups

Social robots are joining the existing educational system in a new role as "teachers", requiring a reasonable division of labor as "Co-Teaching" and changing teaching methods and processes to gradually form a new educational structure. As educational theorist Papert (1993) suggests, robot-assisted activities have great potential for improving

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classroom teaching, enabling more effective learning when children actively construct objects in the external world.

Whittier and Robinson (2007) used Evobots LEGO robots in the high school science curriculum to teach evolution-related knowledge. Through evolution demonstrations, they illustrated that the origin of life is debatable, but evolution is an undeniable fact. This not only provided students with opportunities to learn English vocabulary but also helped them better grasp scientific concepts through hands-on exploration. It also facilitated the generalization and application of knowledge in areas such as mechanical friction and engineering design [7].

Marina Fridin (2014) used the social robot NAO to assist a teacher in explaining the story of “The Ugly Duckling” to 10 kindergarten children. In addition to conveying the story’s content and plot, the robot incorporated activities such as singing and movement. The results showed that the children not only enjoyed interacting with the robot but also were able to follow its instructions and engage in imitation and communication with their peers [8].

Shichong Wang et al. (2019) used a social robot conducted research on “Quadratic Equations” in a middle school mathematics class. Students watched video resources, and the robot presented learning resources and questions to the students through smart mobile devices. The social robot provided answers to questions it could solve, while questions it couldn’t answer were sent back to the teacher’s side. After the lesson, the teacher received evaluation reports from all learners as well as the class’s learning progress, which served as a reference for designing future lessons. In this experiment, the social robot acted as another “teacher” in the classroom, not only providing support with data but also taking on some teaching tasks. The teacher focused on the “educational” aspect of teaching, cultivating and enhancing their awareness of “human-robot collaboration” with the students [9].

Anna-Maria et al. (2021) used the NAO robot to teach engineering principles to first-year non-engineering students. They conducted three controlled experiments to assess students’ enjoyment, knowledge acquisition, and surprise levels. In the first session, students taught by human instructors outperformed the robot group in terms of knowledge acquisition, but the robot group reported higher levels of enjoyment and surprise during the class. In the second session, both groups were taught by the robot, and the students who had previously been taught by the robot performed better in knowledge acquisition and enjoyment compared to the group taught by human instructors. However, the surprise level was not as high as in the first session. This led to the conclusion that a high level of surprise may initially distract students’ attention and lead to decreased learning outcomes, but over time, it can become a motivating factor for learning [10].

Chao Tan et al. (2021) introduced a social robot in a middle school biology classroom for class discussions. The results showed that the introduction of the social robot created a more positive classroom atmosphere, enhanced students’ agency, significantly increased their collaborative inquiry skills, and enriched the methods of

classroom teaching discussions. It also stimulated teachers’ lifelong learning capabilities [11].

2.2 The application of social robots in the group of children with ASD

From a timeline perspective, foreign countries began applying social robots in autism intervention research in 1976. In contrast, domestic exploration in China in this field began with the “The AuRoRA Project” in 2009 [12]. In a recent review by Yang Ning (2022), a systematic literature review method was used to conduct a re-review of 25 systematic literature reviews on social robots from the Web of Science database spanning from 2012 to 2022. The findings revealed that there were fewer research reviews focused on the topic of “social robots and special education”. Additionally, there was also limited attention given to the application of social robots in specific populations, such as individuals on the autism spectrum disorder, under the classification of research subjects [13].

Sandra Costa et al. (2016) confirmed the increase in joint attention and interactive behaviors of two 7-year-old children with autism through the use of LEGO robots as intermediaries in different course activities. The study also demonstrated effective skill transfer [14].

Biyu Huang et al. (2019) conducted a study on social interactive behaviors in 24 children with autism using the NAO robot. The study examined behaviors such as proximity, contact, imitation, gaze fixation frequency, gaze fixation duration, and skin conductance response. The experimental activities included greeting, finger pointing, and gaze following. The findings revealed that children with autism exhibited a stronger inclination and preference for interaction with the NAO robot. Skin conductance analysis showed that the rate of change in skin conductance was higher during interaction with the robot compared to human therapists. The children displayed positive emotions, pleasant expressions, and behaviors, and the robot was able to induce active social behaviors in children with autism [15].

Nazerke Rakhymbayava et al. (2021) conducted a 21-day, one-on-one human-robot social skills intervention training using the NAO robot with 11 children aged 4 to 11 with ASD in a rehabilitation center. They observed the children’s engagement, efficacy scores, and duration of interaction. The results showed that the sustained engagement of children with ASD with the robot remained relatively high even after an extended period of time. Familiarity with the environment and activities increased overall engagement for each child [16].

Yun Hong et al. (2022) selected four children with autism as participants and conducted a study on executive function intervention using the “Wukong” robot in a rehabilitation institution’s laboratory. The results demonstrated that robot-based executive function intervention programs effectively improved the executive function of children with autism and had a certain maintenance effect [17].

Based on existing research, social robots have shown promising results in the development and implementation of intervention programs for children with ASD. These

interventions have demonstrated positive effects on improving communication difficulties and reducing repetitive behaviors in children with ASD. Social robots have also shown significant potential in facilitating social interaction among these children.

3. Discussion

With the advancement of modernization, intelligent technology has accelerated the reform of teaching methods and facilitated personalized learning for students. The educational mode of human-robot collaboration can leverage the respective strengths of teachers and artificial intelligence, promoting comprehensive student development. As part of the construction of smart education, the smart classroom environment has become an integral component of smart campuses [18]. Social robots are gradually making their way into regular classrooms. In the future, social robots will be deeply integrated into classrooms, reducing the heavy workload on teachers, improving the quality of education and teaching, and achieving scalable educational equity and access to high-quality resources [9].

Numerous studies have shown that social robots can be “valuable” companions in autism intervention therapy and intervention teaching. However, current research mainly focuses on one-on-one human-robot interaction rather than the typical group learning environment. The research settings often take place in rehabilitation facilities rather than regular classrooms, and social robots are rarely seen in classrooms of special education schools and related institutions. In a pilot study conducted by Geoffrey Louie (2022), it was found that children with ASD exhibited similar learning behaviors with both human and robot teachers. This is a positive result as it demonstrates the feasibility of deploying robots in a real classroom environment. Schools are a crucial stage in a child’s life, and it is important to provide an inclusive environment where they can fully develop their potential [19].

There have also been discussions on the practical guidelines for using robots in classrooms, including ethical considerations, data security, information literacy, and other issues. As an instructional tool, social robots offer opportunities and challenges for teachers. Teachers should consciously decide how to harness the potential of social robots instead of using them haphazardly. Introducing learners to new technologies is not a bad thing as it prepares children to face the world they will live in [20].

With the development of technology, social robots will become more autonomous and intelligent, enabling them to make greater contributions in classrooms. However, they lack emotions and do not possess human-like thinking. Teacher identity, or what it means to be a teacher, is an evolving complex collection of personal roles, behavioral norms, and social and cultural expectations [21]. They are not only managers of instruction but also supporters of creative learning and providers of accessible learning resources.

4. Experiment

4.1 Social robot

Our experiment will be conducted using the social robot NAO (Figure 1). NAO is an intelligent robot developed by SoftBank Robotics. It has functionalities such as speech, movement, and motion. It can express various emotions like anger, fear, sadness, and can infer changes in emotions by learning the body language and facial expressions of the interacting individuals.



Figure 1: Social Robot: NAO

4.2 Location

The experimental location for our human-robot collaboration course is in a regular classroom at the Special Education School in City S (Figure 2).



Figure 2: Special Education School Classroom

4.3 Participant

The participants were recruited from special education schools in City S. Inclusion criteria were as follows:

- 1) diagnosed with autism spectrum disorder,
- 2) aged 9-12 years,
- 3) no hearing impairments,
- 4) able to understand simple instructions,
- 5) no severe problem behaviors such as aggression.

Written informed consent form was obtained from all participants’ parental guardians, teachers and experts from the special education school prior to the study. And Participants’ parental guardians were informed that they could withdraw from the study at any time if they did not wish to participate or wished to discontinue their involvement.

4.4 Implementation Plan

The experiment consists of two main parts. The first part focuses on the intervention program for group interaction skills, which includes activities such as self-introduction, roll-call, imitation, following instructions, and group activities. This intervention program aims to promote communication and improve joint attention among the children. It serves as a necessary skill for the subsequent integration of social robots in the classroom and facilitates human-robot collaboration in teaching.

The second part of the experiment involves designing the intervention based on the curriculum materials in special education school and the curriculum design of special education teachers. The goal is to enable the social robot to adapt to the teaching pace of the special education teacher and properly integrate into the traditional classroom settings.

4.5 Coding and Scoring

The classroom sessions will be recorded using three cameras throughout the entire duration of the experiment. The recorded videos will be encoded by three observers to measure the children's learning behaviors, including participation, attention, communication, and other target behaviors. Interviews and questionnaires will be conducted with teachers and parents to gather their feedback. Each session will also be evaluated to refine the subsequent curriculum and experimental design.

5. Conclusion

Our research will be a brand-new attempt, guided by the curriculum design of special education teachers. The focus of the experiment will be the campus curriculum for children with autism, with supplementary interventions commonly used for them. By integrating methods such as Applied Behavior Analysis, Structured Teaching, and The Social Motivation Theory commonly employed for children with autism, the curriculum of special education school will be structurally designed, and pilot experiments will be conducted to explore the effectiveness of social robots in the classrooms of children with ASD and their classroom performance. This analysis aims to uncover the potential application of social robots in the classrooms of children with ASD. Moreover, based on existing literature, social robots have already been extensively practiced in classrooms with typically developing children. In the future, social robots may serve as effective mediators in classrooms for both typically developing children and children with autism, promoting the development of inclusive education.

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