Journal of Engineering Science and Technology
Special Issue on 3rd BPNIC2025 Vol. 21 No. 2 (2026) 73-80

HOW ROBOTS CAN HELP CHILDREN WITH AUTISM LEARN AND THRIVE: A STEP TOWARD ACHIEVING THE SDGS

W. WAGINO*, ZAENAL ABIDIN, ACEP OVEL NOVARI BENY, ONNY FRANSINATA ANGGARA, SAIFUDIN YAHYA

Universitas Negeri Surabaya, Surabaya, Indonesia
*Corresponding Author: wagino@unesa.ac.id

Abstract

This study presents the design, development, and experimental evaluation of a socially assistive robot intended to support social and communication skill development in children with Autism Spectrum Disorder (ASD). The proposed system, Hello Bot 2.0, integrates a mobile-based control interface, microcontroller-based motion control, and interactive visual-auditory feedback to enable structured and predictable human-robot interactions. A Design-Based Research framework was applied and operationalized as an applied engineering workflow consisting of system design, implementation, and experimental testing. The robot was evaluated through a two-month pilot trial involving ten children with ASD aged 3-7 years and ten teachers in a therapeutic-educational setting. Experimental observations focused on engagement duration, response frequency, and interaction consistency during robot-assisted activities. The results indicate increased user engagement and improved responsiveness during structured interaction sessions, demonstrating the feasibility of the proposed robotic system as a complementary therapeutic tool. This study contributes to applied robotics research by providing an experimentally validated robotic system for autism intervention and supports inclusive technology development aligned with sustainable education goals.

Keywords: Autism, Autistic spectrum, Robot, Therapy, Social interaction.

1. Introduction

Robotic systems have become an important application of engineering technologies aimed at supporting human-centred services, including healthcare and special needs education [1]. In recent years, socially assistive robots have attracted increasing attention as complementary tools in autism intervention due to their ability to deliver structured, consistent, and predictable interactions [2, 3].

These characteristics are particularly suitable for children with Autism Spectrum Disorder (ASD), who often experience difficulties in social communication, emotional recognition, and joint attention during conventional human-mediated interactions. Previous studies have reported regarding special needs education [4-8]. Specifically, they demonstrated that robot-assisted therapy can enhance engagement, reduce social anxiety, and facilitate the learning of basic social behaviours through controlled visual, auditory, and gestural cues [9, 10].

Various robotic platforms, such as NAO, Milo, and other interactive humanoid or semi-humanoid systems, have been developed to support emotional recognition, imitation, and communication training for children with ASD [11, 12]. These systems commonly employ simplified facial expressions, regulated speech, and repetitive interaction patterns to create a supportive learning environment. Despite promising results, most existing systems are developed in high-resource contexts and remain limited in terms of accessibility, adaptability, and local contextualization [13-20]. In addition, several studies emphasize educational outcomes without sufficiently detailing system architecture, control mechanisms, and experimental validation from an engineering perspective.

To address these limitations, this study focuses on the design, development, and experimental evaluation of a socially assistive robotic system tailored for autism intervention. The proposed robot, Hello Bot 2.0, integrates mobile-based control, embedded microcontroller architecture, and multimodal interaction features to support social and communication skill development in children with ASD. The novelty of this work lies in the applied engineering implementation and experimental validation of a locally developed robotic system, providing evidence of its feasibility as a complementary therapeutic tool within inclusive education and rehabilitation settings.

2. Methodology

This study employed an applied engineering approach framed within Design-Based Research to develop and evaluate a socially assistive robot for autism intervention. The research stages consisted of system requirement analysis, robotic system design, hardware-software integration, and experimental testing.

The robot integrates a smartphone-based control interface, an Arduino microcontroller, a Bluetooth communication module, and multimodal visual-auditory feedback. Experimental evaluation was conducted through a two-month pilot trial involving ten children with Autism Spectrum Disorder aged 3-7 years and ten teachers. Observational data focusing on interaction duration, response frequency, and engagement consistency were collected to assess system functionality and feasibility in a therapeutic-educational environment.

3. Results and Discussion

The developed robotic system employs a smartphone-based control interface utilizing an accelerometer and keypad to transmit motion commands to the robot, as illustrated in Fig. 1. Communication between the smartphone and the robot is established via a Bluetooth connection, enabling real-time data transfer. Once connected, user input is processed by the microcontroller, allowing the robot to perform basic movements such as forward and backward motion, left and right turns, tilting actions, and stopping. These movements are executed through DC motors controlled based on accelerometer data, providing responsive and predictable robot behaviour during interaction sessions.

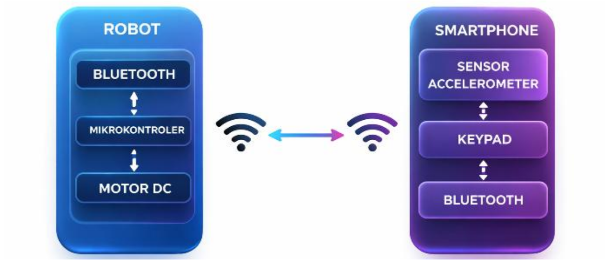

Fig. 1. Robot control.

The hardware communication architecture is shown in Fig. 2. The Arduino Uno serves as the primary control unit, receiving serial data from the HC-05 Bluetooth module connected to the smartphone. This data is processed to control the DC motors via the L298N motor driver. In parallel, the Arduino communicates with a Raspberry Pi using serial communication, allowing the same control data to be used for generating synchronized visual and auditory outputs. The Raspberry Pi processes the data to display images and play sounds corresponding to robot actions, supporting multimodal interaction during therapeutic activities.

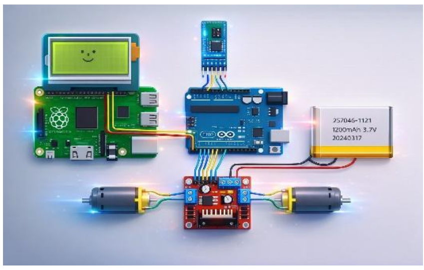

Fig. 2. Bluetooth module with microcontroller.

The overall system workflow is summarized in Fig. 3. The software development process began with designing an integrated control workflow that combines accelerometer and keypad inputs on the smartphone. This structured workflow ensures consistent system behaviour and minimizes programming errors. The smartphone application functions as the main controller, while the Arduino program acts as the command interpreter and actuator controller. This modular software architecture enables stable operation and simplifies system debugging and refinement.

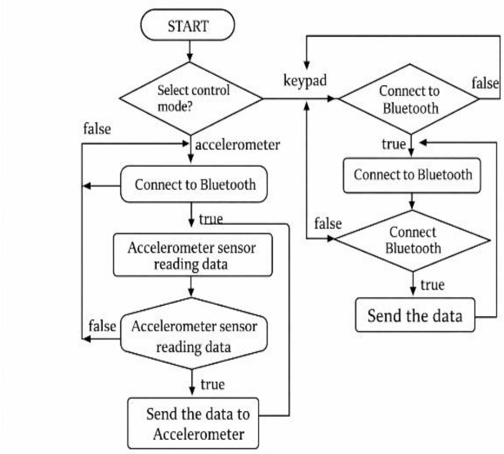

Fig. 3. Flowchart of the robot working with a smartphone.

Beyond system implementation, the robot was designed specifically to support autism therapy by addressing the social and communication challenges commonly experienced by children with Autism Spectrum Disorder (ASD). The development process of Hello Bot 2.0, illustrated in Fig. 4, followed sequential stages from conceptual design to system integration. The robot was intentionally designed to provide structured and predictable interactions, as such interaction patterns are beneficial for children with autism.

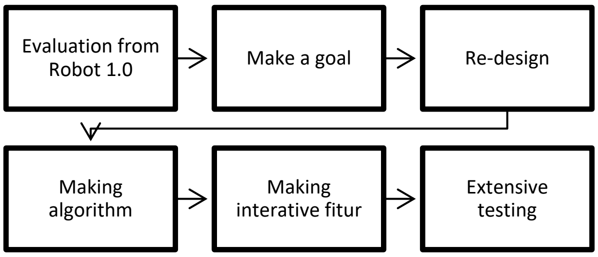

Fig. 4. Step of making Hello Bot 2.0.

The robot's functional objectives include facilitating emotional expression, encouraging responsive behaviour, and supporting basic social interaction. To achieve these goals, the robot incorporates a friendly and non-threatening physical appearance, expressive visual displays, and simple gesture-based movements. Emotion expression and response are delivered through coordinated facial displays, body motion, and voice output, allowing children to associate actions with emotional cues in a controlled environment.

Interactive scenarios and educational activities were embedded into the system to enhance social engagement and communication practice. The robot adapts interaction difficulty based on user engagement, allowing personalized responses through behaviour-based adjustment mechanisms. Although advanced learning algorithms are applied at an applied level, the system enables basic personalization by responding to observed interaction patterns. Safety considerations were prioritized throughout the design process, ensuring smooth surfaces, the absence of detachable small parts, and intuitive system operation suitable for young users.

The advantages and interaction features of Hello Bot 2.0 are summarized in Table 1, highlighting non-verbal cues, verbal communication support, visual-auditory feedback, and interactive activities. These features collectively create a structured learning environment that supports social engagement, communication practice, and emotional understanding.

Table 1. Advantages of Hello Bot 2.0.

Advantages	Information
Non-verbal cues and Gestures	Touch and Movement: A lot of social robots have touch sensors built in, so they react to physical cues like pats, embraces, and button presses. To teach appropriate physical contact skills, robots such as NAO can respond to touch by playing pre-recorded messages or performing certain actions. [21].
	Look, expressions on the face, Children are frequently engaged by robots through eye contact and facial movements. Children's comprehension of emotions and the development of cooperative attention depend heavily on these nonverbal clues. [22].
Verbal communication	Speech Recognition, Proficient robots recognize and react to basic spoken orders or inquiries from kids through speech recognition technology. Children can practice speaking and communicating in a safe setting with the assistance of this interaction. [23].
	Pre-Recorded Messages, Robots can deliver pre-recorded messages or prompts, which can be useful for initiating conversations or guiding activities. This method provides a predictable and structured way for children to practice verbal communication [24].
Visual and Auditory Feedback	Screen Displays: Some robots incorporate screen displays that show images, videos, or text to complement verbal instructions. This multi-modal approach can aid in the comprehension and retention of information [25].
	Sound and Music, Robots may use sound effects or music to maintain engagement and provide auditory feedback during interactions. This can be particularly effective for children who respond well to auditory stimuli [26].
Interaction	Role-Playing and Storytelling, Robots often engage children in role-playing games or storytelling activities, which can improve social skills and creativity [27, 28].
	Educational Games and Activities, Educational robots can conduct learning activities that teach academic skills like counting, reading, and problem-solving [29].
	Emotion Recognition and Expression. For instance, they might display different facial expressions and ask the child to identify the emotion or encourage the child to express how they feel using visual aids [30, 31].
	The structured and predictable nature of robot interactions provides a comfortable learning environment for children with autism. Studies have shown that these interactions can lead to improvements in social engagement, communication skills, and emotional understanding [32].

To evaluate system feasibility, pilot trials were conducted over two months involving ten children with ASD aged 3-7 years and ten accompanying teachers. Observational data collected during robot-assisted sessions indicated increased engagement duration, more frequent response behaviours, and improved interaction consistency compared to initial sessions. Teachers reported that the predictable interaction patterns supported sustained attention and facilitated social interaction practice. These findings demonstrate that the developed robotic system is technically functional and practically feasible as a complementary tool for autism intervention in therapeutic and educational contexts.

4. Conclusion

This study demonstrated the feasibility of a socially assistive robotic system designed to support social and communication development in children with Autism Spectrum Disorder. The proposed Hello Bot 2.0 integrates embedded control, mobile-based interaction, and multimodal feedback to enable structured and predictable interactions. Experimental observations from a two-month pilot trial indicated increased engagement and interaction consistency during robot-assisted sessions. These findings suggest that the developed system can function as an effective complementary tool in autism intervention. The study contributes to applied engineering research by providing an experimentally evaluated robotic solution that supports inclusive and sustainable educational technologies for special needs populations.

Acknowledgments

Universitas Negeri Surabaya Competitive Research Program funded this study.

References

1. Ahillon Jr, R.C.; Cadiong, S.R.C.; Tomeldan, A.B.; Belgira, A.C.B.; Ayaya, A.R.A.; Paredes, A.D.M.; Balajadia, D.J.G.; Sumandal, R.G.F.; Basilio, L.D.; and Quindra, K.C. (2025). Evaluation of robotics class in a private school in the Philippines. *ASEAN Journal of Educational Research and Technology*, 4(1), 23-32.
2. Onojah, A.A.; Aderele, S.O.; Ahmed, F.T.; Nathaniel, S.; and Onojah, A.O. (2022). Perception of special needs undergraduates on the use of assistive technology for academic purposes. *ASEAN Journal of Community and Special Needs Education*, 1(2), 37-44.
3. Olatunji, I.; and Babalola, E.O. (2022). Undergraduates with special needs' awareness towards the use of assistive technology for learning at the university level. *ASEAN Journal of Community and Special Needs Education*, 1(2), 45-54.
4. Faddillah, R.N.; Nandiyanto, A.B.D.; and Bilad, M.R. (2022) Literacy program for elementary school students about inclusive education in recognizing children with special needs. *ASEAN Journal of Community and Special Needs Education*, 1(1), 1-8.
5. Kurniawan, T. (2022). Design of places of worship for people with special needs. *ASEAN Journal of Community and Special Needs Education*, 1(1), 17-22.

6. Fitri, S.D.; Muktiarni, M.; and Mupita, J. (2022). Strengthening literacy in children with special needs during courageous learning with family support in learning during a pandemic. *ASEAN Journal of Community and Special Needs Education*, 1(1), 29-36.
7. Musayaroh, S. (2022). Behaviors of concern to special education teachers in their classroom: class characteristics and class composition predictors. *ASEAN Journal of Community and Special Needs Education*, 1(2), 55-60.
8. Kurniawati, K. (2022). Efforts to improve the vocabulary of Indonesian language for 1st-grade elementary students with hearing impairment for through the application of mnemonic. *ASEAN Journal of Community and Special Needs Education*, 1(2), 81-88.
9. Ng, P.M.H. (2018). Robots and children learning differently: A brief review of robot applications for young children. *Asia Pacific Journal of Developmental Differences*, 5(2), 227-245.
10. Pashevich, E. (2022). Can communication with social robots influence how children develop empathy? Best-evidence synthesis. *AI and Society*, 37(2), 579-589.
11. Qidwai, U.; Kashem, S.B.A.; and Conor, O. (2020). Humanoid robot as a teacher's assistant: Helping children with autism to learn social and academic skills. *Journal of Intelligent and Robotic Systems,* 98(3), 759-770.
12. Robaczewski, A.; Bouchard, J.; Bouchard, K.; and Gaboury, S. (2021). Socially assistive robots: The specific case of the NAO. *International Journal of Social Robotics*, 13, 795-831.
13. Conti, D.; Cirasa, C.; Di Nuovo, S.; and Di Nuovo, A. (2020). Robot, tell me a tale!" A social robot as tool for teachers in kindergarten. *Interaction Studies*, 21(2), 220-242.
14. Saleh, M.A.; Hanapiah, F.A.; and Hashim, H. (2021). Robot applications for autism: A comprehensive review. *Disability and Rehabilitation: Assistive Technology*, 16(6), 580-602.
15. Walker, G.; and Venker Weidenbenner, J. (2019). Social and Emotional Learning in the age of virtual play: Technology, empathy, and learning. *Journal of Research in Innovative Teaching and Learning,* 12(2), 116-132.
16. Crompton, H.; Gregory, K.; and Burke, D. (2018). Humanoid robots supporting children's learning in an early childhood setting. *British Journal of Educational Technology*, 49(5), 911-927.
17. Cañamero, L.; and Lewis, M. (2016). Making new "New AI" friends: Designing a social robot for diabetic children from an embodied AI perspective. *International Journal of Social Robotics*, 8(4), 523-537.
18. Peribañez, E.; Bayona, S.; San Martin, J.; Verde, A.; Garre, C.; Leoste, J.; and Pastor, L. (2023). An experimental methodology for introducing educational robotics and storytelling in therapeutical activities for children with neurodevelopmental disorders. *Machines*, 11(6), 629.
19. Baraka, K.; Melo, F.S.; and Veloso, M. (2019). Interactive robots with model-based 'autism-like'behaviors: Assessing validity and potential benefits. *Paladyn, Journal of Behavioral Robotics*, 10(1), 103-116.

20. Syriopoulou-Delli, C.K.; and Gkiolnta, E. (2022). Review of assistive technology in the training of children with autism spectrum disorders. *International Journal of Developmental Disabilities*, 68(2), 73-85.
21. Turja, T.; Taipale, S.; Niemelä, M.; and Oinas, T. (2022). Positive turn in elder-care workers' views toward telecare robots. *International journal of social robotics*, 14(4), 931-944.
22. Deng, E.; Mutlu, B.; and Mataric, M.J. (2019). Embodiment in socially interactive robots. *Foundations and Trends in Robotics*, 7(4), 251-356.
23. Chan, J.S.; Deng, K.; and Yan, J.H. (2021). The effectiveness of physical activity interventions on communication and social functioning in autistic children and adolescents: A meta-analysis of controlled trials. *Autism*, 25(4), 874-886.
24. Lai, M.C.; Anagnostou, E.; Wiznitzer, M.; Allison, C.; and Baron-Cohen, S. (2020). Evidence-based support for autistic people across the lifespan: Maximising potential, minimising barriers, and optimising the person-environment fit. *The Lancet Neurology*, 19(5), 434-451.
25. Cheetham, D. (2019). Multi-modal language input: A learned superadditive effect. *Applied Linguistics Review*, 10(2), 179-200.
26. Geller, J.; Winn, M.B.; Mahr, T.; and Mirman, D. (2020). GazeR: A package for processing gaze position and pupil size data. *Behavior research methods*, 52, 2232-2255.
27. Supartini, T.; Weismann, I.T.J.; and Hengki, W. (2020). Development of learning methods through songs and movements to improve children's cognitive and psychomotor aspects. *European Journal of Educational Research*, 9(4), 1615-1633.
28. Tsikinas, S.; and Xinogalos, S. (2020). Towards a serious games design framework for people with intellectual disability or autism spectrum disorder. *Education and Information Technologies*, 25(4), 3405-3423.
29. Lan, Y.J.; Hsiao, I.Y.; and Shih, M. F. (2018). Effective learning design of game-based 3D virtual language learning environments for special education students. *Journal of Educational Technology and Society*, 21(3), 213-227.
30. Fane, J.; MacDougall, C.; Jovanovic, J.; Redmond, G.; and Gibbs, L. (2018). Exploring the use of emoji as a visual research method for eliciting young children's voices in childhood research. *Early Child Development and Care*, 188(3), 359-374.
31. Sarabzadeh, M.; Azari, B.B.; and Helalizadeh, M. (2019). The effect of six weeks of Tai Chi Chuan training on the motor skills of children with autism spectrum disorder. *Journal of Bodywork and Movement Therapies*, 23(2), 284-290.
32. Molinillo, S.; Aguilar-Illescas, R.; Anaya-Sánchez, R.; and Vallespín-Arán, M. (2018). Exploring the impacts of interactions, social presence and emotional engagement on active collaborative learning in a social web-based environment. *Computers and Education*, 123, 41-52.