Humanoid Robot-Assisted Learning for Level 1 Autistic Children: Developing Test Plans to Enhance Number Recognition Skills

Siti Nurul Mahfuzah Mohamad[1,*], Norshahidatul Hasana Ishak[1,2], Sazilah Salam[1], Zulisman Maksom[1], Mohd Adili Norasikin[1], Norazah Mohd Nordin[3], Nor Hafizah Adnan[3], Juanita[4], Muhammad Hafizi Mohd Ali[5]

[1] Fakulti Teknologi Maklumat dan Komunikasi, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia
[2] Kolej Pengajian Pengkomputeran, Informatik dan Media, Universiti Teknologi Mara, 40450 Shah Alam, Selangor, Malaysia
[3] Faculty of Education, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[4] Universitas Muhammadiyah Purwokerto, Indonesia
[5] Kum Hoi Engineering Industries Sdn Bhd, No. 5, Lot, 550, Jalan Subang 2, Taman Perindustrian Subang, 47610 Subang Jaya, Selangor

ABSTRACT

Keywords:
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Autism spectrum disorder (ASD) impacts the social, communication, and cognitive development of affected individuals. Level 1 autism, the mildest form of ASD, presents unique challenges in the acquisition of crucial skills such as number recognition, which serves as a foundational aspect of children's cognitive development. Recent studies have shown that humanoid robots can offer effective intervention strategies for autistic children, fostering learning in a structured, engaging, and interactive environment. This study aims to develop and evaluate test plans using humanoid robots to enhance number recognition skills in Level 1 autistic children. The study included a comprehensive literature review, focusing on previous research involving humanoid robots in autism intervention and number recognition skill development. Based on the findings, a test plan was designed to address the unique learning needs of Level 1 autistic children in number recognition. Participants were selected based on specific criteria, ensuring a diverse and representative sample. The humanoid robot's capabilities and features were detailed, emphasizing its role in facilitating the test plan. The research methodology outlined the test plan components, implementation procedure, data collection, and analysis techniques. Results demonstrated that the humanoid robot-assisted test plan was effective in enhancing number recognition skills among Level 1 autistic children. The participants exhibited significant improvements in their abilities to identify and manipulate numbers, as well as increased engagement and motivation in learning tasks. The study also revealed that the interactive and supportive nature of the humanoid robot fostered a positive learning environment, which contributed to the observed improvements in number recognition skills. The implications of these findings extend to the broader field of autism intervention, highlighting the potential benefits of incorporating humanoid robots into educational and therapeutic programs for autistic children. The study also offers valuable insights for the development of test plans specifically tailored to the needs of Level 1 autistic children in acquiring number recognition skills. Furthermore, it emphasizes the

* Corresponding author.
E-mail address: mahfuzah@utem.edu.my

importance of continued research in this area to optimize the use of humanoid robots for intervention and skill development in children with ASD.

1. Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by varying degrees of social, communication, and behavioural impairments. Level 1 autism, the mildest form of ASD, requires support for individuals to address challenges in social communication, interaction, and restricted or repetitive patterns of behaviour [1]. One essential skill for children's development is number recognition, which serves as a foundational aspect of their cognitive growth [2]. Humanoid robots, such as NAO or Pepper, have shown the potential to facilitate number recognition learning and other educational outcomes for children with autism [3]. These robots provide a structured, engaging, and interactive environment that may cater to the unique needs of children with Level 1 autism [4]. The present study aims to investigate the effectiveness of using humanoid robots to enhance number recognition skills in Level 1 autistic children. Specifically, it seeks to develop and evaluate test plans that incorporate robot-assisted learning activities tailored to the needs of these children. By exploring the potential benefits of humanoid robots in facilitating number recognition learning, this research aims to contribute to the broader field of autism intervention and promote the use of advanced technology for skill development in children with ASD.

Despite advancements in educational and therapeutic interventions for children with autism spectrum disorder (ASD), there remains a need for innovative approaches to enhance cognitive skills, particularly among Level 1 children with autism [1,2]. Number recognition is a fundamental cognitive skill that plays a critical role in early childhood development and academic success [2]. However, the current literature on robot-assisted interventions for children with autism predominantly focuses on social skills and communication [5,6], with limited research exploring the impact of such interventions on specific cognitive skills, such as number recognition.

Additionally, many previous studies have not adequately addressed the importance of individualized learning experiences or considered the long-term effects and sustainability of the observed improvements in cognitive skills [4,7]. Moreover, the generalizability of the findings is often limited due to a focus on specific populations or settings [4].

The present study aims to address these gaps by investigating the effectiveness of a humanoid robot-assisted test plan in enhancing number recognition skills among Level 1 children with autism across diverse socio-economic backgrounds and educational settings. This research seeks to explore the adaptability of the robot-assisted test plan in providing tailored learning experiences that cater to the unique needs of each child, as well as assess the long-term effects and sustainability of the intervention. By doing so, the study aims to contribute valuable insights to the field of autism intervention and inform the development of future robot-assisted learning strategies that effectively address the cognitive needs of Level 1 children with autism.

2. Related Works

2.1 Existing Research on Humanoid Robots and Autism Intervention Focusing on Number Recognition

Previous studies on humanoid robots and autism intervention have explored the use of humanoid robots in teaching or improving skills in children with ASD, with a focus on number recognition in some cases. One study that explored the use of humanoid robots for teaching number concepts to children with autism spectrum disorder (ASD) was conducted by Pitsch *et al.,* [8]. The study used a humanoid robot named NAO as a teaching tool and found that it effectively improved the children's number recognition and related skills.

Alhaddad *et al.,* [9] examined the use of humanoid robots for teaching social and communication skills to children with ASD. Although the study did not specifically focus on number recognition, it found that using robots effectively improved the children's overall communication skills. Another study by Karunarathne *et al.,* [23], explored using a humanoid robot named Tega as a math tutor in a kindergarten classroom. The results showed that using the robot effectively improved the children's math skills, including number recognition.

In Wainer *et al.,* [10], a humanoid robot named KASPAR was used for social and communication skills training in children with ASD. Although the study did not specifically focus on number recognition, it found that using the robot effectively improved the children's overall social engagement and learning. Ahijado and Nicolás [24] examined the effectiveness of a humanoid robot-based intervention for teaching number and geometry concepts to children with autism. The study found that the intervention effectively improved the children's number recognition and related skills.

Scassellati, Admoni and Matarić [7] investigated using a humanoid robot as a tool for teaching gestures to children with autism. The study found that the robot effectively improved the children's understanding and use of gestures. Almeida, Menezes and Dias [25] systematically reviewed previous studies on using robots for autism intervention. The review found that robots effectively improved various skills, including number recognition, in children with autism. A meta-analysis by Tapus *et al.,* [11] examined the effectiveness of social robots in autism intervention. The analysis found that social robots effectively improved various skills, including number recognition, in children with autism.

In summary, several studies have explored the use of humanoid robots for teaching number recognition and related skills to children with ASD. These studies have generally found that the use of robots is effective in improving children's number recognition and related skills, as well as other skills such as communication and social engagement. Table 1 summarises a comparison of the existing research.

2.2 The Role of Test Plans in Assessing and Fostering the Development of Number Recognition Skills

Test plans are essential for assessing and fostering the development of number recognition skills in children with autism spectrum disorder (ASD). Test plans can help educators and therapists track progress and tailor interventions to meet the specific needs of each child. One study that highlights the importance of test plans is "Humanoid Robots as a Supportive Tool in the Education of Children with Autism Spectrum Disorder" by Pitsch *et al.,* [8]. This study used a test plan to evaluate the effectiveness of a humanoid robot called NAO in teaching number concepts to children with ASD. The test plan included a pre-test, post-test, and follow-up assessment to track the children's progress in number recognition skills. The results showed that using the robot effectively improved the children's number recognition skills.

This study used a test plan to evaluate an educational software program designed to teach basic math skills to children with ASD. The test plan included pre- and post-assessments to measure the children's progress in math skills. The results showed that the software program was effective in improving the children's math skills.

Table 1
Previous research on humanoid robots and autism intervention focusing on number recognition

Author(s)	Participants	Methodology	Subjects	Findings	Data Analysis
Pitsch *et al.,* [8]	18 children with ASD, aged 6-12	Pretest-post-test control group design	Teaching number concepts using a humanoid robot called NAO	The use of NAO improved the children's number recognition and related skills	Statistical analysis using t-tests
Cabibihan *et al.,* [4]	9 children with ASD, aged 7-9	Case study	Teaching social and communication skills using humanoid robots	The use of robots improved the children's overall communication skills	Qualitative analysis of video recordings and field notes
Karunarathne *et al.,* [23]	47 kindergarten children	Quasi-experimental design	Teaching math skills using a humanoid robot called Tega	The use of Tega improved the children's math skills, including number recognition	Statistical analysis using mixed effects models
Wainer *et al.,* [10]	19 children with ASD, aged 5-10	Randomized controlled trial	Training social and communication skills using a humanoid robot called KASPAR	The use of KASPAR improved the children's overall social engagement and learning	Statistical analysis using mixed effects models
Ahijado and Nicolás [24]	10 children with ASD, aged 5-7	Quasi-experimental design	Teaching number and geometry concepts using a humanoid robot	The intervention improved the children's number recognition and other related skills	Statistical analysis using t-tests
Scassellati, Admoni and Matarić [7]	3 children with ASD, aged 9-13	Case study	Teaching gestures using a humanoid robot	The robot improved the children's understanding and use of gestures	Qualitative analysis of video recordings and field notes
Almeida, Menezes and Dias [25]	Meta-analysis of 15 studies	Systematic review	Various skills, including number recognition, taught using robots	Robots were effective in improving various skills, including number recognition, in children with ASD	Meta-analysis of effect sizes

Test plans can also help educators and therapists identify specific areas of strength and weakness in a child's number recognition skills. For example, a study by Arshad *et al.,* [15] used a test plan to evaluate the number recognition skills of children with ASD. The test plan included assessments of number recognition, counting, and basic arithmetic. The results showed that the children with ASD had particular difficulties in counting and basic arithmetic, highlighting areas for targeted intervention.

While existing research has provided valuable insights into the potential benefits of using humanoid robots in educational and therapeutic settings for children with autism, several gaps in the literature warrant further investigation. The present study aims to address these gaps and contribute

to a deeper understanding of the effectiveness of humanoid robot-assisted interventions for Level 1 children with autism, particularly in enhancing number recognition skills.

i. <u>Limited focus on specific cognitive skills:</u> Much of the current literature on robot-assisted interventions for children with autism has focused on social skills and communication. However, there is a need for more research on the impact of such interventions on specific cognitive skills, such as number recognition, which plays a crucial role in early childhood development.

ii. <u>Individualized learning experiences:</u> While previous studies have demonstrated the effectiveness of humanoid robots in engaging children with autism, there is limited research on how these robots can provide tailored learning experiences that cater to the unique needs of each child. The present study explores the robot-assisted test plan's adaptability and capacity to accommodate diverse learning styles and preferences.

iii. <u>Long-term effects and sustainability:</u> The majority of existing research on robot-assisted interventions for children with autism has been conducted over relatively short periods. More longitudinal studies are needed to assess the long-term effects and sustainability of the observed improvements in cognitive skills.

iv. <u>Diverse populations and settings:</u> Many previous studies have focused on specific populations or settings, limiting the generalizability of the findings. The present study seeks to explore the effectiveness of the humanoid robot-assisted test plan across different socio-economic backgrounds and educational settings, thereby contributing to a more comprehensive understanding of the potential benefits of this technology in autism intervention.

By addressing these gaps in the current literature, the present study aims to provide a more nuanced understanding of the potential benefits and challenges associated with humanoid robot-assisted interventions for Level 1 children with autism, with a specific focus on enhancing number recognition skills. This research may inform the development of future robot-assisted learning strategies and underscore the importance of integrating advanced technology into educational and therapeutic settings for children with autism.

2.3 Robot for Special Education

They are many robots being used to help ASD children. There are two types of robots, humanoid and non-humanoid robots. Humanoid robots, being like humans, have shown better results than other robots. According to Qidwai, Kashem and Conor [12], the shape, size, and aesthetics of the robot, as well as its ability to interact with the children, make significant differences in the therapeutic process. Children with autism appeared to be more comfortable interacting with robots than humans. The rapid development of computer and robotic technologies in the last decade is giving hope to perform earlier and more accurate diagnosis of ASD, as well as more effective, consistent, and cost-conscious treatment. Besides the reduced cost, the main benefit of using technology to facilitate treatment is that stimuli produced during each session of the treatment can be controlled, which not only guarantees consistency across different sessions but also makes it possible to focus on a single phenomenon, which is difficult even for a trained professional to perform and deliver the stimuli according to the treatment plan [13]. Due to the inclusion of social robots in therapy, it has even been observed how the children's limited interests and repetitive behaviour have improved [14].

Robots represent a concrete scaffold for cognition in learning that includes improving children's social skills. The results of previous studies have indicated that there is a high interest in improving the relationship between robots and children with ASD. For example, social interactions began to flourish as children with ASD began to share the robots with their peers and communicate with each other, thus enhancing their social skills [15]. Hence, robots can be used as a mediator tool to get feedback from children with autism or to encourage them during the intervention sessions. The robots can attract the subjects using body gestures, releasing sound (music or sound instruction), blowing bubbles, or rewarding them for following or achieving proper interaction instruction [16].

Fig. 1. Robots used for children with autism

2.4 Cognitive and Social Skills for Children with Autism in Numeracy Game

This conceptual framework was adapted by a numeracy game named Math Marks the Sport and Long Pole (*Galah Panjang*) by incorporating elements guided by Piaget's theory of cognitive development, Gagne's theory of information processing and Vygotsky's theory of social development. This has been chosen by researchers as it is suitable for the physical ability of children with autism, and it can be played either indoors or outdoors. Through this numeracy game-play approach, it is hoped that children will be able to demonstrate the response of cognitive and social skills. At the same time, such numeracy games can also stimulate the cognitive and social development of children with autism. This is because play activities are important in children's development and serve as a tool for social interaction. Besides that, this game may stimulate the cognitive and social development of children with autism.

The focus of this model is cognitive and social skills among children with autism. The interaction elements for cognitive skills include:

  i. Action
  ii. Curiosity
  iii. Object representation
  iv. Problem-solving
  v. Concept building
  vi. Understanding building
  vii. Working memory.

These seven elements were adapted from previous researchers in her study. Meanwhile, there are six elements in social skills which are:

i. sensitive to friends
ii. building relationships
iii. joining together
iv. imitating
v. giving ideas
vi. appreciating.

Previous researchers also adopted these elements. The play model adopted in this study emphasises mutual involvement that requires help and guidance from adults or peers and can positively influence the cognitive, communication, socio-affective and motivational to children with autism [17].

3. Methodology

In order to design and evaluate a test plan using humanoid robots to enhance number recognition skills in Level 1 children with autism, an appropriate methodology would involve a mixed-methods approach, combining quantitative and qualitative data collection and analysis by Creswell and Poth [26]. This methodology allows for a comprehensive understanding of the effectiveness of the test plan and the participants' experiences.

The inclusion criteria for the children are:

i. diagnosed with mild autism
ii. registered as a Level 1 student in the special education program and the integrated school system of Malaysia based on their IQ level
iii. diagnosed with verbal autism
iv. be able to care for oneself without the need for a carer
v. have no severe physical impairments
vi. have no unusual behavioural problems such as hyperactivity (uncontrollable), being violent or severe mental issues
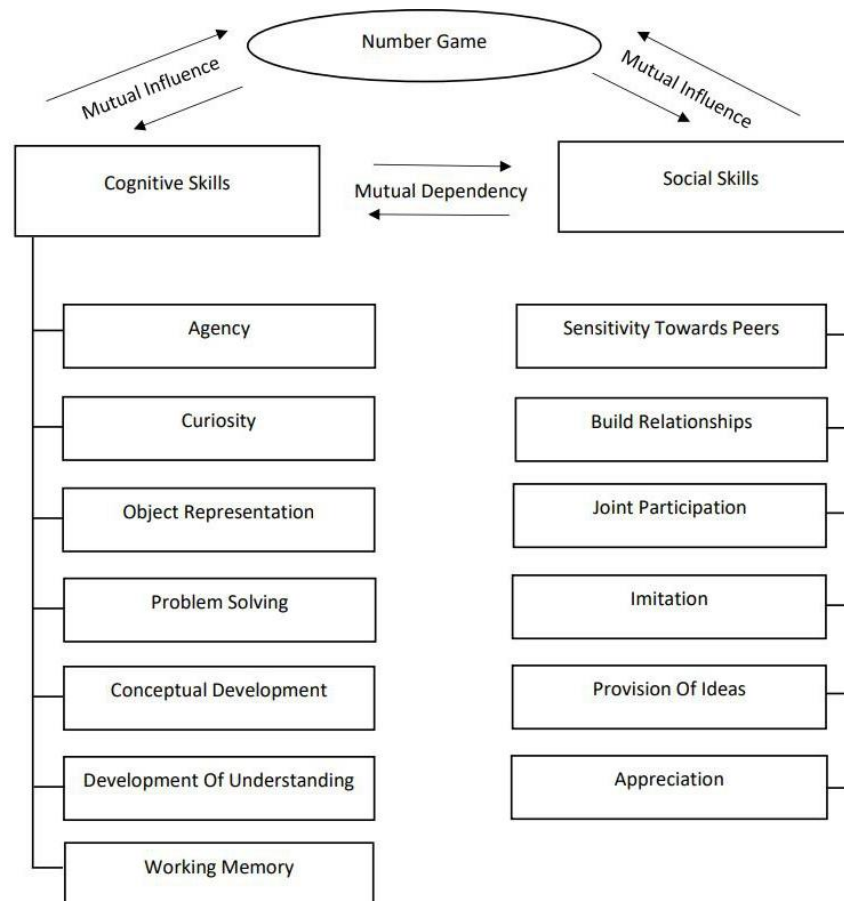vii. have no internal ailments such as chronic seizures or heart failure.

Fig. 2. Conceptual framework for cognitive and social skills for children with autism in numeracy game

The guidebook contains tools for determining the appropriate educational placement for students with learning disabilities. This determination is based on the assessment of five key factors:

i.   the child's capacity for self-management
ii. appropriate behaviour
iii. object manipulation
iv. effective communication in Malay
v.   performance in specific mathematical tasks.

After evaluating these exams, the kid is thereafter assigned to a suitable classroom within the integrated school's special education program and closely observed for advancement and growth.

This study implements a humanoid robot known as NAO, which is a product from Aldebaran with a proven track record in educational and therapeutic settings [3]. The robot is equipped with auditory communication capabilities and touch sensors for interaction. The robot was programmed to deliver the number recognition test plan effectively.

Robotic intervention fosters engaging and demanding learning environments. This could aid educators in managing the challenges and demanding obligations associated with teaching youngsters diagnosed with autism. This study provides evidence supporting the effectiveness of robotic intervention as an assistive learning tool for children with autism. It enhances engagement, attention, and interest in learning. Nevertheless, more real case studies to investigate the

effectiveness of robotics in learning other subjects, including language, science and many more are very much welcomed [18].

3.1 Pilot Test 1 (Autism Learning Laboratory, UKM)

The primary purpose of the pilot test was to gather preliminary data on the interactions, behaviour, and engagement between the student and the humanoid robot during the implementation of the test plan. Conducted at the Permata UKM facility, this case study aimed to identify any potential modifications required for the final test plan and offer insights into the efficacy of the robot-assisted intervention.

For this pilot test, two children (Level 1 autistic) aged between 5 (female) and 9 years old (female) were involved. It is to ensure a balanced representation of genders. The participants were selected from diverse socio-economic backgrounds and educational settings to fully understand the potential benefits and challenges associated with the humanoid robot-assisted test plan.

The process of obtaining consent from the participant's parents or guardians began one month prior to the pilot test. This allowed sufficient time for the parents or guardians to review the information about the study, ask any questions, and make an informed decision about their child's participation. In addition to the informed consent, parents and guardians were provided with regular updates on their child's progress throughout the pilot test.

By recruiting participants from different backgrounds and educational settings, the pilot test aimed to explore the effectiveness and adaptability of the humanoid robot-assisted test plan in addressing the unique needs of Level 1 children with autism in various contexts. The diverse sample also offered the opportunity to identify any potential barriers or challenges that may arise during the implementation of the test plan, providing valuable insights for its further refinement and optimization.

Fig. 3. Pilot test 1 at autism learning laboratory UKM

3.2 Pilot Test 2 (Sekolah Kebangsaan Bukit Beruang)

The pilot test at Sekolah Kebangsaan Bukit Beruang is a modification from Pilot Study 1. The improvements made from Pilot Study 1 have been implemented in Pilot Study 2. The result from Pilot Study 2 shows major improvement in terms of content and communication between students and robot NAO. The experiment was conducted with the help of three special needs teachers from the school. Five children (four male and one female) were involved in this testing. All five children fulfil the criteria for the experiment. This pilot testing procedure aims to assess the impact of using the NAO robot on enhancing cognitive skills and learning in children with autism.

Fig. 4. Pilot test 2 at Primary School Melaka

3.3 Test Plan Design

Before the experiment begins, the teacher briefs the children with autism about the NAO robot. It is to give the children an overview of the robot. The next step is a briefing session about the experiments to the special needs teachers. The teachers observe the demonstration, and practice according to the demonstration recording.

At first, the student will observe the teachers interact with the robot by answering the robot's yes or no questions. Then, a comprehensive test plan that integrated various activities to promote engagement and number recognition skills among the participants is designed. The activities include interactive elements such as dancing and singing, focusing on enjoyable and familiar songs like "If You're Happy and You Know It, Clap Your Hands," as the special needs teachers recommended. These interactive components are intended to foster a positive learning environment and enhance the children's motivation during the sessions.

In order to determine whether the test plan is effective, researchers conduct post-test assessments. After the singing activity, the children must learn the numbers with the NAO robot. There are three activities in learning numbers:

i. learning numbers from 1 to 10
ii. matching the numbers
iii. sorting the numbers.

At the end of the lesson, researchers conduct a pre-test assessment to establish the participants' baseline number recognition skills [19]. The evaluation was given to test the effectiveness of the activities. Implementation of the test plan is suitable in a controlled environment, such as a special education classroom or therapy centre. Figure 3 shows the flow of the test plan after pilot testing for the next experiment.

3.4 Procedure

i. Implement the test plan in a controlled environment, such as a special education classroom or therapy centre.
ii. Pre-test assessments should be conducted to establish the participants' baseline number recognition skills [19].
iii. Deliver the test plan using the humanoid robot over a specified period (e.g., 8-12 weeks) Conduct post-test assessments to evaluate the effectiveness of the test plan.
iv. Procedure: The test plan, consisting of various number recognition activities, was administered over a specified period (e.g., 4 weeks). The humanoid robot, programmed to deliver the activities effectively, interacted with the children individually in a controlled environment.

3.5 Activities during the experiment: Mathematics for Fun: Duration (1 Hour 5 Minutes – 2 Weeks)

Utilise the humanoid robot for specifically designed activities related to cognitive ability and social behaviour [15]. Learn numbers from 0 to 10. This package includes teaching-learning activities, a robot to assist the teacher, and exercise material to test the understanding of children learning with autism. Activities refer to the Textbook for Level 1 Special Needs education.
The objectives of activities are as follow:

i. To enhance the ability to make decisions and solve problems.
ii. To pronounce and count numbers using fingers and tools.
iii. To recognize numbers 0 to 10.
iv. Students are able to match the number.
v. Students can sort numbers (increasing/decreasing).
vi. Measure the student's performance by:
   - Learning effectiveness
   - Attention.
vii. Learning effectiveness is measured based on the result of the pre-test and post-test for cognitive purposes.
viii. Attention - Measure of Attention by using involvement in the teaching process (ITP) [20] based on:

- Difficulty in paying attention (PA)
- The inability to sit (ITS)
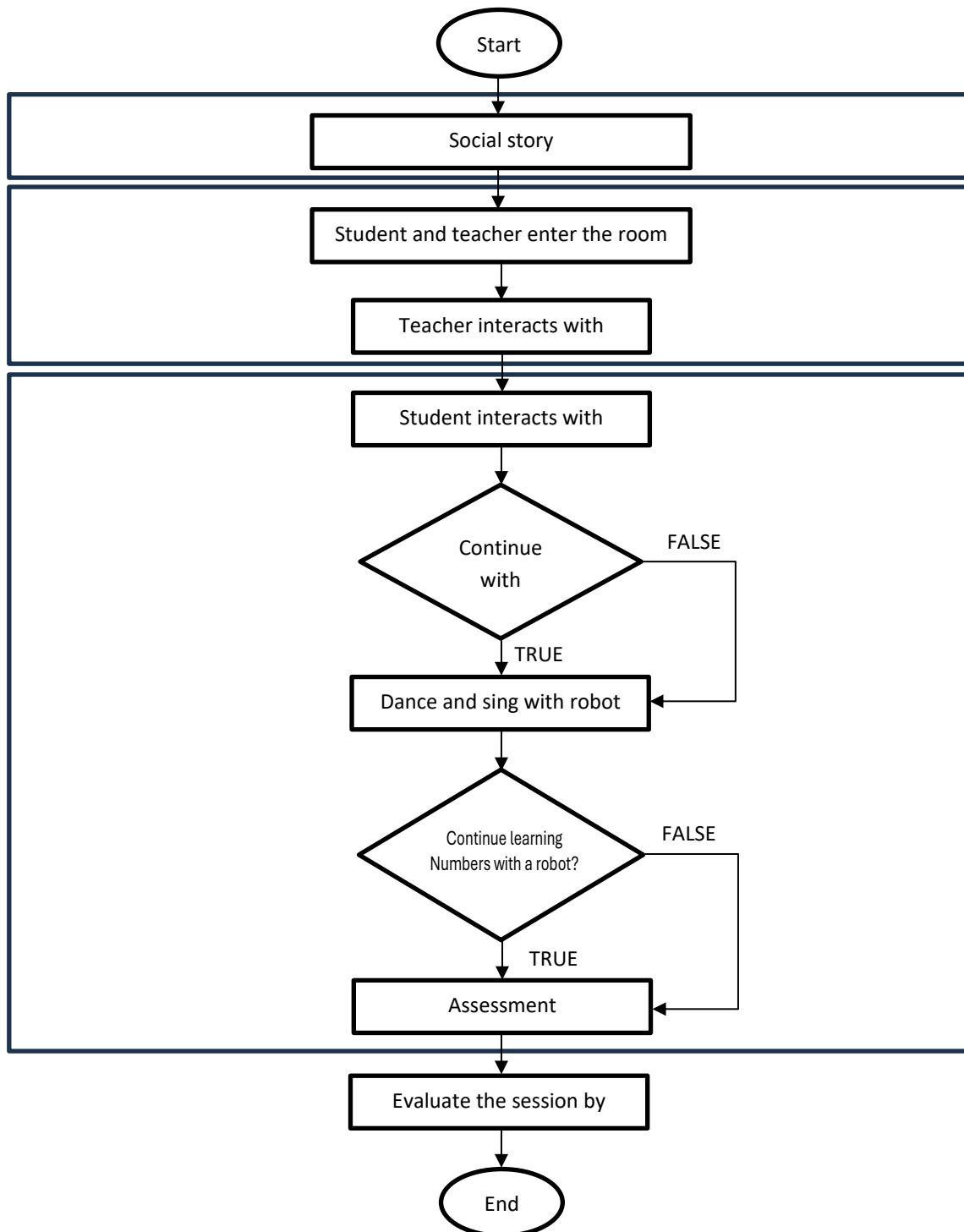- Difficulty in following instructions (FI).

Fig. 3. Flow of the test plan

3.6 Data Collection and Analysis

For quantitative data, data are collected through pre-test and post-test assessment scores to measure improvements in number recognition skills. Analysis of the data can then be done using statistical tests (e.g., paired t-tests or Wilcoxon signed-rank tests) [21].

For qualitative data, the researchers conduct semi-structured interviews with teachers, and therapists to gather their insights on the participants' progress, the test plan's effectiveness, and the overall experience with the humanoid robot [22]. Qualitative data can be analysed using thematic analysis to identify key themes and patterns.

Both quantitative and qualitative data were collected to assess the interaction and engagement between the student and the robot. Video recordings of the sessions were analysed to observe the children's behaviour and engagement during the activities. In addition, semi-structured interviews with the children's teachers, and therapists were conducted to gain their perspectives on the intervention.

The pilot test provided valuable insights into the effectiveness of the robot-assisted test plan. The children demonstrated increased engagement and motivation during the learning activities, which could be attributed to the interactive and supportive nature of the humanoid robot. Furthermore, the personalized approach employed by the robot allowed for individualized learning experiences, catering to each child's specific needs.

4. Findings and Discussion

The primary objective of this study is to develop a viable test plan for future studies specifically for evaluating the effectiveness of the humanoid robot-assisted in improving number recognition skills among Level 1 children with autism.

4.1 Pilot Test 1

To summarize the findings, the girls demonstrated a high level of responsiveness and were able to follow the instructions provided by the humanoid robot during the learning activities. Their engagement with the tasks indicated that the robot-assisted test plan's interactive and supportive nature effectively maintained their interest and motivation throughout the sessions. The boys exhibited a slower response to the instructions provided by the humanoid robot. The learning activities and instructions took them (the boys) approximately one hour to complete. This observation highlights the importance of adapting the test plan to accommodate each child's individual needs and pace, ensuring that they can benefit from the intervention at their comfort level.

4.2 Pilot Test 2

Specifically, the aim of the Pilot Test 2 is to evaluate whether a humanoid robot-assisted test plan will enhance number recognition skills among Level 1 children with autism. The results of the pilot test provided additional insights into the children's ability to follow instructions and engage with the learning activities. The results demonstrate the potential of a humanoid robot-assisted test plan in enhancing number recognition skills among Level 1 children with autism. However, these findings also underscore the need for a personalized approach that caters to each child's unique learning styles and preferences, ensuring an optimal and supportive learning experience. Implications for the

final test plan: the test plan was refined to ensure optimal delivery and effectiveness. Feedback from the stakeholders highlighted areas for improvement, such as the need for additional reinforcement learning strategies and more varied activities to maintain the children's interest.

From the findings above, here are the suggestions for further improvement:

i.   Set up an introduction before the lesson starts. Introduce the humanoid robot using both photos and videos to make students aware and familiar with the robot.
ii. Introduce the humanoid robot, but the teacher should slowly reveal the robot to the student, covering it with a black curtain, and let the student interact with the robot.

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