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Autism Robot (AuRo) Framework to Facilitate Learning for Children with Autism Spectrum Disorder (ASD)

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ABSTRACT

There is growing evidence that using robots in educational settings could benefit children with autism spectrum disorder (ASD) by enhancing their cognitive abilities like attention, behaviour, and social skills. The objective of this paper is designing content for children with autism using a robot as the mediator by using AuRo model that implement VAK learning style. To create robot learning content for young children to learn mathematics, specifically about numbers, the framework for this goal is crucial. Therefore, an autism robot (Auro) model was suggested for this study to assist children with ASD in learning about numbers. The framework's elements were chosen following a thorough analysis of the ASD literature. Through expert reviews with academic specialists and technologists, the proposed framework was iteratively assessed. Based on the feedback offered by experts, a modified version of the framework was created. The main findings from expert review showed that the proposed framework's structure, components and details have been effectively refined. The evaluation of the prototype involving children with ASD will determine the effectiveness of the AuRo Model for future work by giving them pre-test and post-test.

1. Introduction

This paper focuses on designing content for children with autism using a robot as the mediator. There are varieties of mediums currently used to help children with autism in improving their daily life activities and cognitive such as virtual reality, augmented reality, smartphones and others. The target users are children with autism or known as ASD children. The employment of a robot to enhance people's cognitive function and learning abilities is the main topic of this study. Numerous

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studies have been conducted on robot intervention for autistic kids. Since most studies, including some for-learning improvement, concentrate on daily life skills rather than mathematics, this study will concentrate on designing for mathematics with the subtopic of numbers, basing on recommendations from teachers of students with special needs. The fundamental justification for the selection of the subtopic is that before learning mathematics, they must have a solid understanding of numbers. The results of the preliminary study indicate that the biggest number of children in Malaysia's Special Needs class, also known as PPKI, have autism, thus this research is limited to studying only those children. Children with Autism in Malaysia's PPKI from 2018 to 2022 are depicted in Figure 1. As can be seen from the graph below, the majority of autistic students are in primary school. For every sort of school, the number of them is rising yearly. This fits nicely with the elementary school-focused research in the study.

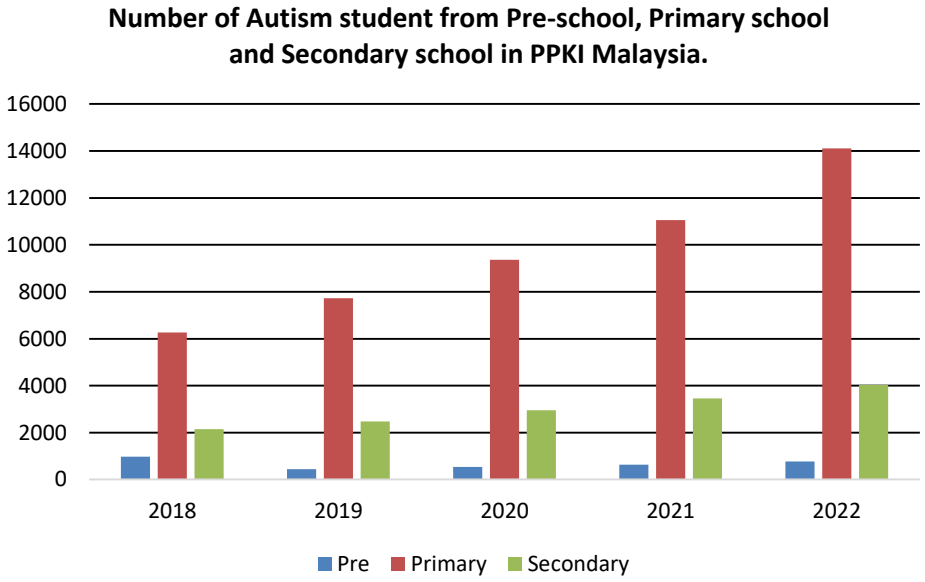

Fig. 1. Number of MBK students from preschool, Primary school and Secondary school in PPKI Malaysia from 2018 to 2022 [1-5]

1.1 Cognitive Theory

Cognitive theory is a learning theory psychology that attempts to explain human behaviour by understanding thought processes. Humans are thought to be rational creatures who make decisions based on what makes the most sense to them. When comparing the human mind to a computer, the term "information processing" is frequently used to describe the mental process. The theories created from this approach can be divided into two groups, according to [6]: those that deal with the impairments in social cognition of autistic children and those that deal with their difficulties in non-social or general cognition. Psychologists and behavioural specialists have studied the underlying mechanisms behind the behaviours of people with autism from a cognitive perspective. Children with autism also reported issues with focus, organisation, planning, and memory, among other cognitive skills. Consequently, it has an impact on the cognitive abilities of autistic children [6]. The principles of cognitive learning theory suggest:

i. people are active
ii. learning and development depend on learners' experiences
iii. learners construct understanding
iv. prior knowledge influences knowledge construction
v. learning requires a social environment, practice, and feedback [7]

1.2 Behavioural Theory

Behavioural Theory, Behavioural Psychology, or Behaviourism is most known as Behaviourism. Behaviourist theory, which is a psychological theory in its essence, founded by J.B. Watson, is a theory of native language learning, advanced in part as a reaction to traditional grammar. According to [8], the behavioural theory derived from such work has four tenets:

i. autistic children's behaviours are consistent with laws of learning derived from the behaviour of other organisms
ii. autistic children have many separate behavioural difficulties best described as a developmental delay
iii. despite their difficulties, many autistic children learn as much as other human beings in specific environments
iv. their difficulties can be viewed as a mismatch between a deviant nervous system and average or typical environments rather than as a disease

However, they are still important unanswered questions which require further research. Behaviourism is a theory of learning, and learning theories focus on how people respond to events or stimuli rather than emphasizing internal factors that motivate our actions. These theories explain how experience can change what people do [9]. There is not so much discussion on behavioural theory implemented in children with autism.

1.3 VAK learning style model (Visual, Auditory, Kinesthetics)

VAK stands for Visual, Auditory and Kinesthetics. It is a learning style model that combines three knowledge delivery methods. VAK is a learning model which points out that the learning process must take advantage of all senses owned by students. In contrast, the VAK learning model combines auditory, visual, and kinesthetics senses. This learning model emphasises direct learning experience through visualization, auditory, and kinesthetics. According to [10-12], the difficulty in understanding mathematical connections experienced by students can be caused by students learning style since it determines how students can engage things through their senses. The researcher combines these three learning styles in her research, and the results show the significance of implementing these styles in Mathematics. Effective and efficient learning can be achieved using visual, auditory and kinesthetics [13], focusing on human observation channel vision, hearing and feeling. It can be used for three types of users: visual learners who prefer learning via seeing; auditory learners prefer listening; kinesthetics learners or tactile learners best learn through feeling or doing- experiencing, such as moving, touching, and doing [11]. There are commonalities among the emotional needs of students with autism as well. Students with autism tend to multitask more often than those who are single-task persistent, preferring numerous breaks throughout work periods as opposed to focusing on a single job until it is finished. It has been found that students with autism share similar

preferences for learning styles [15]. Table 1 shows media elements that relate to the learning style [10,11].

Table 1
Media elements that relate to the VAK learning style

Learning style	Related Media Elements
Visual	Images, pictures, videos, diagrams, charts, and other visual information.
Auditory	Aural communication, sounds, music, dialogue, discussion, and reading materials.
Kinaesthetic	Interactive activities, active listener, and practical-task orientation.

Social interaction and communication skills significantly impact human development, learning, and well-being. The lack of these elements can hinder individuals from successfully integrating into a complex society. Emotional awareness is essential, especially for children with autism and their parents or caregivers.

1.4 Special Education

Special education provides students with identified disabilities specialized instruction designed to meet their unique learning needs, allowing them to develop to their fullest potential. Special education is important for special needs people. There are a few categories of special education in Malaysia, also known as Special Educational Needs (MBK), such as *Ketidakupayaan Penglihatan* (BL), *Ketidakupayaan Pendengaran* (BD), *Ketidakupayaan Pertuturan*, *Ketidakupayaan Fizikal*, *Masalah Pembelajaran* (BP) and *Ketidakupayaan Pelbagai* (MD). In Malaysia, the Special Education Integration Programme (PKKI) has been employed to assist MBK in providing instruction at public schools. One of the government's programmes aims to assist the locals and make sure they are not neglected. Statistics show that number of global Autistic cases has increased yearly. According to [14], ASD occurrence depends on gender, as it happens four times more in boys compared to girls. In the United States, statistics denote that one child in every 91 children is diagnosed with ASD. Additionally, one out of every 68 newborns in Malaysia, specifically Sibu, has been found to have an ASD issue [17]. The number of autistic students registered in schools each year has increased, according to reports from the Malaysian Ministry of Education (MoE).

1.5 Human-Robot Interaction (HRI)

A study by Krishnasamy in [15], the use of technology, information, and communication is thought to have a substantial impact on the teaching and learning sector. Research into the techniques and outcomes of human interaction with any robot, such as humanoid or non-humanoid robots, is known as human-robot interaction [16]. A few elements of HRI can be measured, such as gaze, communication, affect, attention, imitation, and proxemics [17]. Meanwhile, when robots are involved in the interaction, HRI may benefit people with ASD by increasing their interest in tasks, levels of attention, and unique social behaviours, including shared attention and spontaneous imitation [18]. The HRI is believed to be able to assist children with autism in socialising, communicating, and engaging in enjoyable behaviours through robot-based intervention. HRI architecture is a novel method for autism research [14].

To support the learning style, the robot's specifications should be considered. In this study, the robot can move and communicate while making sound to entice kids. In turn, the children feel at ease and close to the robot due to speech recognition. Hence, having access to technology and digital tools significantly enhances learning for all students, including those who have autism [19]. The

effectiveness of the robot used is supported by Laman in his study mentions that real-time interaction with virtual things makes it feasible to depict robotics technology with human-robot interaction and wireless connection, necessitating the development of other technology that allows the most effective use of robots to help humans with their work [20]. The robot of choice is programmable and humanoid. Currently, some types of robots can be helpful.

This study outlined how the AuRo model was used to help teach children with autism. The humanoid robot, NAO was chosen because it is thought that due to its appeal, it might divert autistic children's attention to activities [21]. Therefore, this study's outcomes will focus on applying the AuRo model using the humanoid robot NAO to assist children with autism and enhance their cognitive skills during teaching and learning sessions by adopting the VAK learning style. There is lack of learning with robot that focusing in Mathematics, as for this study Mathematics has been chosen as the topic of study matter, with Numbers as the subtopic. These children with autism will learn to:

i. recognize numbers from 1 to 10
ii. matching numbers
iii. sort numbers in ascending and descending order

2. Methodology

The study framework should be established before the research begins so that it can act as a roadmap for the study's completion with a specific goal in mind. A well-designed research framework ensures that the study is carried out methodically and rigorously, resulting in credible results. Figure 2 shows the flow for creating the experimental framework for the autism robot (AuRo), which could assist children with autism spectrum disorder (ASD) participate in learning sessions.

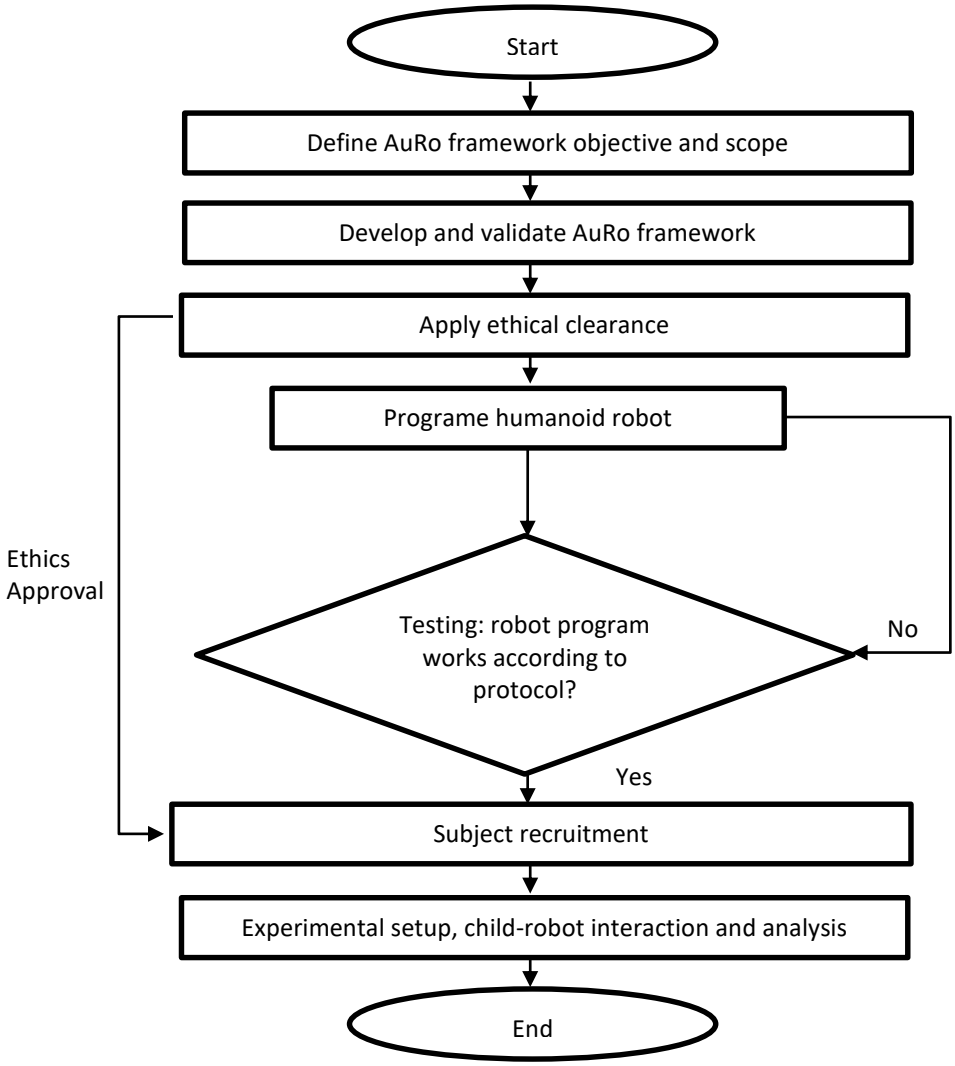

Fig. 2. Flow of the research planning

2.1 AuRo Framework Objective and Scope

The framework of this study focused on the investigation on the effectiveness of a humanoid robot on the cognitive abilities of children with autism through learning sessions in the classroom. In this study, an autism robot (AuRo) model was proposed to help children with ASD learn about numbers from 1 to 10. The learning model was implemented with NAO, the humanoid robot, as a tool to emphasize direct learning experience through visualization, auditory, and kinesthetics for the children.

2.2 AuRo Framework Development and Validation

The construction of Autism Robot (AuRo) model was based on combinations and adaptations of a few frameworks and theories. Given the range of learning methods being employed, it was predicted that the implementation of VAK could increase the involvement of autistic children. Moreover, by using VAK in learning, students will actively participate in learning sessions [13,22]. The main framework used [6] contained two ways of communication. It entailed being active, and the play model used in this study emphasised mutual involvement that necessitated assistance and

direction from peers or adults. It could have a good impact on an autistic child's cognitive, communicative, socio-affective, and motivational development. This study adopted the quasi-experimental design namely the development of AuRo model to be implemented in robot learning Mathematics and effectiveness of using AuRo model in robot based on student performance. The figure below shows a conceptual framework of AuRo model consisting of three sections:

i. Human Robot Interaction (HRI), focusing on attention elements. Two components of learning style and robot to boost the elements. For the learning style, visual, auditory and kinesthetics were employed. Simultaneously, the robot focused on the movement or interaction, sound and speech recognition
ii. Subject Content was the main content for the model. Learning activities were proposed to be used by teachers and students for one subject or one topic. This subject content related to cognitive domain. The subtopic chosen was Numbers
iii. Cognitive Domain had two elements namely social skills and cognitive skills. When it comes to improving a child with autism's cognitive abilities, both of these factors are interdependent.

In this study, the independent variable (IV) was learning method which is:

i. Robot (conventional method)
ii. Traditional learning (traditional method)

In contrast, the dependent variable (DV) was students' performance, measuring learning effectiveness, attention distribution and behaviour change. Meanwhile, the moderator variable was the robot intervention. Figure 3 shows the conceptual model with variables of IV, MV and DV.

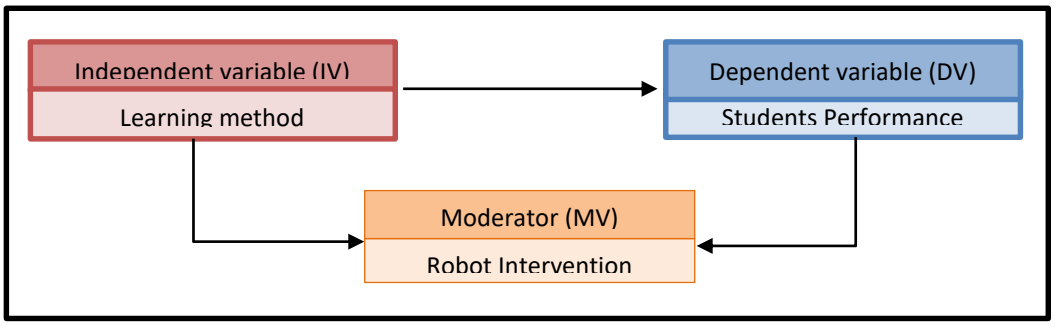

Fig. 3. Conceptual model with variables of IV, MV and DV

In this study, the subtopic "Numbers" was chosen, a component of the Mathematics Level 1 topic according to the Ministry of Education (MOE) Malaysia's curriculum for classes with special needs. Meanwhile, information gathered from teachers all over Malaysia supported the selected subtopic. A list of subtopics from the Malaysian MOE textbook for special needs primary children was included by the researcher in the survey. Six subtopics in the syllabus were:

i. Recognizing Objects
ii. Numbers
iii. Addition
iv. Subtraction
v. Money
vi. Time

50% of the teachers who took part in the survey believed the subtopic of numbers was acceptable for this study for mathematics depends on this particular problem. To understand and learn mathematics, students need to have a fundamental comprehension of numbers.

Before being used in the experiment, the AuRo model was vetted by seven specialists. Expert teachers in special education were among the subject matter experts who checked the material to make sure it adhered to the special education curriculum. The technology experts conducted research on interventions for children with autism had experience utilising technology with children with autism, and studies pertaining to the usage of robotics for children with autism. They were chosen based on their involvement in research and knowledge of technology and autistic children.

2.3 Ethics Application

It is crucial to obtain ethics approval before conducting research involving human participants, including children with autism. Ethical approval is a formal process that ensures that research is conducted ethically and responsibly and that the participants' rights, dignity, and well-being are protected. It is to protect the rights of research participants. It ensures that the research is conducted in a manner that respects the rights of the participants, including their autonomy, privacy, and confidentiality. Ethical approval requires that the researcher obtains informed consent from the participants or their legal guardians.

Besides that, it also ensures the researcher protects the confidentiality and privacy of the participants, including their personal and sensitive information. Finally, ethical approval ensures that the research is conducted following ethical standards and guidelines set forth by the university and organisations that cares for individuals with ASD. Taking ethical concerns more seriously will result in studies that are of higher quality, more applicable to real-world situations, and have a bigger impact on families and kids with ASD.

2.4 Programming of Humanoid Robot

A humanoid robot is a robot that resembles the physical shape of humans. In this study, a humanoid type was chosen to be the robotic mediator due to increasing evidence that children with autism have shown positive outcome when interacting with this type of robot. NAO is a famous humanoid robot widely used in research worldwide. It is 58 cm tall, equipped with seven touch sensors, has a pleasing human-like appearance, and is designed to communicate with people. The robot was programmed using Choregraphe software.

2.5 Testing: Robot Program Works According to Protocol?

The prototype was put through four stages of testing, including alpha, beta, pilot, and user, in order to find any faults immediately and potentially improve the quality of the final product. In addition, testing is crucial for improving reliability and ensuring user expectations. In the Alpha testing, the NAO robot was tested by the team members which included the developer. In this test, some modifications were made to the humanoid robot such as its volume, speed of speech, song, movement and interaction.

In addition, the Beta testing was to measure product feasibility before being widely implemented [24]. The NAO robot and its instruments were tested. While the robot was tested by children with autism, the instruments were tested by special needs teachers. The session had been recorded and observation conducted.

A pilot test proved that the NAO robot could assist teachers and children with autism in learning to improve their cognitive ability. The pilot test was conducted among teachers and children with autism. Given that this was the last stage of testing, it occurred in a real or production setting [23]. The system was also tested via user testing, which was the final step. The NAO robot was to be delivered to the real end users to test its effectiveness. Overall, testing is a critical process that plays a significant role in ensuring the quality, reliability, and performance of a software or products.

2.6 Subject Recruitment

A few criteria on the subjects were identified to fit the scope of this research. The children selection was deemed important in ways in which to get feedback about the prototype. The criteria chosen for the children's selections were:

i. Mild autism
ii. Level 1 student registered in the special education program and the integrated school system of Malaysia based on IQ tests
iii. Verbal autism
iv. Able to care for oneself without the need for a carer
v. No severe physical defects
vi. No unusual behavioural problems such as hyperactivity (uncontrollable) or violent or severe mental issues
vii. No internal ailments such as chronic seizures, heart failure, and others. The standardization of the criteria was essential to acquire good outputs without biasness

The participants of this study were from the learning lab of Autism, Faculty of Education Universiti Kebangsaan Malaysia (UKM). The Learning Lab has employed the Individual Educational Plan (RPI) to administer learning activities according to the pupils' needs and execute planned interventions for each pupil [25]. The participants were diagnosed and their mild autism status verified by medical experts. The Lab has maintained data and profiles for each student.

2.7 Experimental Setup, Child-Robot Interaction and Analysis

Figure 4 indicates the experimental setup for this study. Two camcorders were used to record the session. The data from the video were collected and analysed after series of experiments. NAO robot was placed on top of a table, 30 cm distance from the child. The robot and children faced each other and the former taught the latter to perform activities being programmed. The children were accompanied by their teachers during the experiment sessions. The teacher would initiate the task upon the children readiness to learn. Besides, they would also signal the end of the session subjected to the children's condition. The robot was used to aid students as they learn to maintain their attention and focus, under the teachers' monitoring of the sessions. The teacher assisted students in understanding the robot's instructions whenever they face difficulties.

The researcher was hidden from the children to prevent the children from being distracted. The researcher operated the NAO robot via personal computer and kept track of the experiment to record any valuable data. A built-in camera in the robot's head was used for monitoring to make sure the process was smooth and any problems were fixed.

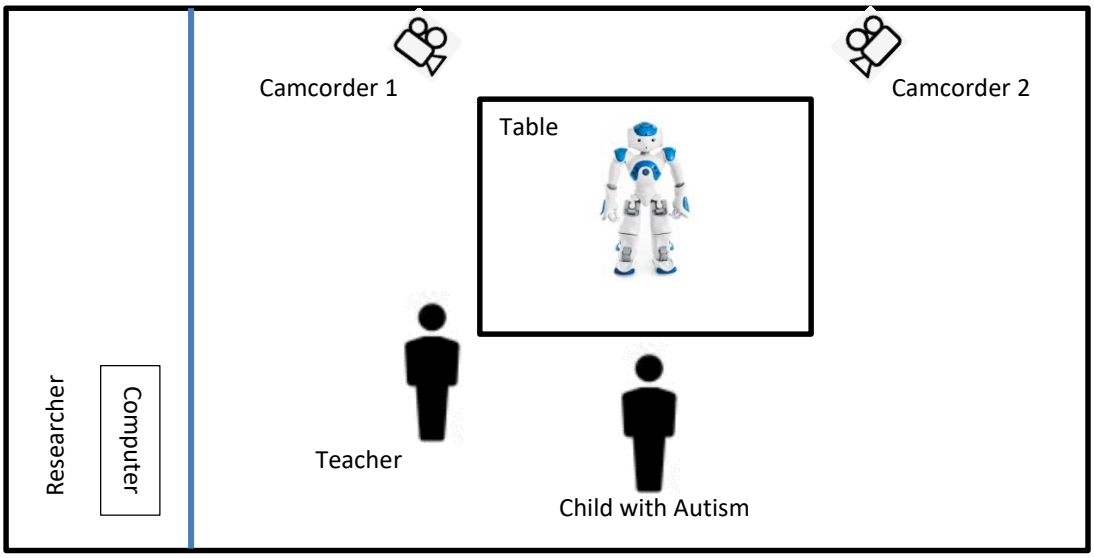

Fig. 4. Experimental Setup

3. Expected Results

The results from the research will be used to evaluate the effectiveness of the AuRo model. The AuRo model is to be implemented in the three activities namely:

i. Emotions stations
ii. Social activity and finally
iii. Mathematics for fun

Figure 5 shows the AuRo Teaching activities. Figure 5 shows the AuRo Teaching activities. This teaching activities is the outcome from the evaluation of the expert. This AuRo teaching activities will be tested during the testing phase in evaluation of the effectiveness of the AuRo model by using Humanoid robot NAO.

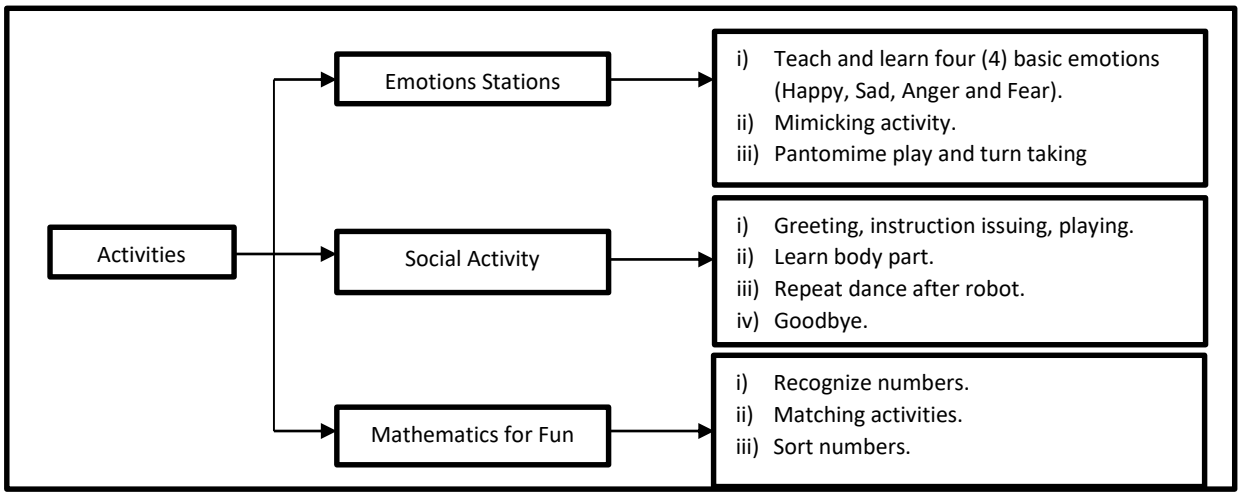

Fig. 5. AuRo Teaching activities

"Emotion stations" will teach four basic emotions by playing Pantomime play and taking turns in guessing and showing emotions. The four emotions selected are:

i. Happiness
ii. Sadness
iii. Anger
iv. Fear

Teaching emotions addresses empathy and emotion regulation (ER) impairments, which are important underlying factors for many atypicality manifested in ASD [23]. This activity is to make the children with autism familiar with the NAO robot.

Meanwhile, the "Social activity" is aimed to enable autistic children to use different social rules in different social situations and to follow instructions in new activities. These activities will test the behaviour of the children by using Quality of Interactions (QI) based on measuring:

i. Eye contact
ii. Proximity
iii. Verbal interaction

Eye Contact (EC) is measured based on the number of times during the session that the child turns to the teacher or the robot or makes eye contact. Proximity (PR) is determined based on the number of times each child gets up from his seat to approach the partner conducting the session and if he or she wants to touch the partner. Verbal Interaction (VI) examines the degree to which each child speaks spontaneously to the teacher or robot.

Finally, "Mathematics for fun" is to help them enhance their ability to make decisions and solve problems. A humanoid robot is specifically designed for activities related to cognitive ability and social behaviour [27]. In this session, Involvement in the Teaching Process (ITP) will be measured namely:

i. Difficulty in paying attention (PA) - when spoken to, measured by the number of times he does not answer the questions straight away or the question has to be repeated twice or more, or if he interrupts the partner to say something irrelevant
ii. the inability to sit (ITS) - still to the extent that it disrupts an activity - measured by the number of times the autistic children get up from his seat or leave the defined-space of the activity
iii. difficulty following instructions (FI) - assessed based on the number of times each autistic children follows the rules and instructions of the game straightaway or they have to be repeated twice or more

Besides, effectiveness will also be measured by giving them a test. A study [28] proves that NAO robot can significantly affect the behaviour of children with autism, as supported by [29,30], who found that humanised bodily appearance increases interest in the interaction and leads to more generally good emotional experiences frequently seen by children with autism, which relates to the interaction.

4. Conclusion

The employment of the robot is thought to benefit autistic children by enhancing their cognition and attention. The task is assigned to the NAO robot for this study. Because NAO is a humanoid robot that resembles a human, children will be familiar with it and can interact with it easily. The design's

ultimate goal is to test if the robot can raise autistic children's cognitive and attentional skills. The three created activities—emotion stations, social activities, and Mathematics for fun are used to gauge how attentive and intelligent the children with autism are. Ten individuals from UKM's learning lab have been selected to participate in the experiments. They are chosen using the predetermined criteria. The task is assigned to the NAO robot for this study. Because NAO is a humanoid robot that resembles a human, children will be familiar with it and can interact with it easily. The design's ultimate goal is to test if the robot can raise autistic children's cognitive and attentional skills. The three created activities—emotion stations, social activities, and Mathematics for fun are used to gauge how attentive and intelligent the children with autism are. Ten individuals from UKM's learning lab have been selected to participate in the experiments. They are chosen using the predetermined criteria. The AuRo model's incorporation of the VAK style can benefit autistic children, particularly in terms of their attention and focus. Data about the children's actions and reactions to the robot will be gathered in the future during the project. This may consist of surveys, observations, and videotaping. The effectiveness of the NAO robot in enhancing social skills in autistic children needs to be evaluated after data analysis. In an effort to assist autistic children during the learning session, the NAO robot developed using the AuRo model may be employed.

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