IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received April 10, 2020, accepted May 14, 2020, date of publication June 11, 2020, date of current version July 2, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.3001629

Robots as Assistive Technology Tools to Enhance Cognitive Abilities and Foster Valuable Learning Experiences among Young Children With Autism Spectrum Disorder

NOREEN IZZA ARSHAD[1], AHMAD SOBRI HASHIM[2], MAZEYANTI MOHD ARIFFIN[2,3], NURSHAZLYN MOHD ASZEMI[2], HUI MIN LOW[4], AND AZAH ANIR NORMAN[3]

[1]Positive Computing Research Cluster, Institute of Autonomous Systems, Universiti Teknologi PETRONAS, Seri Iskandar 32610, Malaysia
[2]Computer and Information Sciences Department, Universiti Teknologi PETRONAS, Seri Iskandar 32610, Malaysia
[3]Department of Information Systems, Faculty of Computer Science and Information Technology, Universiti Malaya, Kuala Lumpur 50603, Malaysia
[4]Special Education Program, School of Educational Studies, Universiti Sains Malaysia, Minden 11800, Malaysia

Corresponding author: Nurshazlyn Mohd Aszemi (nurshazlyn_17007352@utp.edu.my)

This work was supported by the Prototype Development Research Grant Scheme (PRGS) awarded by the Ministry of Education, Malaysia, under Grant PRGS/1/2015/SSI09/UTP/02/1.

ABSTRACT This study examines the efficacy of robots as assistive technology (AT) learning tools for children with autism spectrum disorder (ASD). The study attempts to find answers to whether robots as assistive tools can (i) profoundly improve achievement in learning and (ii) provide valuable learning experiences among this group of children. Using LEGO Mindstorms EV3, a robot was built and programmed to teach the basic concept of place value in mathematics. Eight children with ASD, specifically, four females and four males, participated in the single case study, and six special education teachers took part in the interviews. The children participated in both traditional and robotic intervention lessons and were assessed at the end of each session. The results indicate a positive increase in content knowledge and an improved disposition toward learning, thus demonstrating the potential utilization of robots as AT tools for harnessing classroom learning. Data from the interviews with teachers highlighted four valuable learning experiences that occurred in the classrooms as a result of the robotic interventions; namely, with respect to young children with ASD, the AT (1) promoted interest and engagement, (2) increased attention and focus, (3) triggered interactions and communication, and (4) created a happy and fun learning environment.

INDEX TERMS Autism spectrum disorder (ASD), assistive technology (AT), cognitive abilities, LEGO Mindstorms EV3, learning experience, robot.

I. INTRODUCTION

Autism spectrum disorder (ASD) is a neuro-developmental condition that causes atypical social communication and behavior patterns in young children. Today, as many as 1 in 160 children globally are affected by this condition [1]. Many studies have concluded that children with ASD face increased challenges in keeping pace with their typically developing peers [2]–[5]. Accordingly, if these children are not provided with some type of intervention and the right scaffolding, the results can have a detrimental effect on their knowledge and skill development [6].

Previous studies have indicated that the introduction of assistive technology (AT) is beneficial in many ways [7]–[13]. The provision of the right AT is crucial for scaffolding ASD and providing the students with tools that enhance learning [14]. Various types of AT, such as special input devices, avatars, tablets, serious games, virtual environments and robots, are suggested for people with ASD depending on their specific disorder [12], [13].

Recently, there has been positive trend in terms of an increase in research conducted to investigate the

The associate editor coordinating the review of this manuscript and approving it for publication was Chia-Wen Tsai.

potential use of robots as AT for children with ASD [3], [9], [12], [15]–[17]. Based on this research, there is evidence supporting the successful application of robots as AT in many areas that include developments in social sciences [18], [19], communications [20] and education [21]. However, the empirical evidence on how robots as AT tools accommodate the learning of children with ASD is still scarce [12], [14], [17], [22]. Hence, it is crucial for research studies to concentrate on presenting evidence that AT is efficacious in special education and inclusive schools [10], [11], [23], [24]. For example, there should be evidence showcasing ways AT facilitates tough or challenging learning tasks that previously seemed impossible for children with ASD to comprehend [7]. Accordingly, we intend to contribute to increasing awareness of and insight into how robots as AT tools can assist learning and bring valuable experience to children with ASD in classrooms.

This study has chosen a topic in mathematics, specifically, 'place values'. Based on the Malaysian special education and inclusive school system, this topic is taught to Year 4 students. Place value is an abstract concept that involves an understanding of the numbering system. Based on the preliminary work conducted by [25], many children with ASD have difficulty understanding and memorizing numbers. For example, they have difficulty placing numbers according to their place values and tend to invert the numbering places. For instance, children with ASD often recognize '14' as '41,' which reflects a misconception of basic place values. It is also difficult for children with ASD to grasp the basic concept that 14 is equal to 10+4 and 41 is equal to 40+1. Children with ASD are concrete learners, which means they require sensory experience to support their learning. Hence, the role of AT is to serve as a supporting tool with a broader range of functions so that children obtain a richer understanding of the concepts. Another reason for choosing this topic is that it supports the curriculum for early childhood autism.

In an effort to investigate the efficacy of robots as AT tools in the classroom, we developed a robot using LEGO Mindstorms EV3 and programmed it to teach place values. LEGO Mindstorms EV3 was selected from among other diverse models available in the market because of its safe design and its appropriateness for educational purposes. It is an assemblage kit that consists of building block pieces and a programmable control unit that enables the development of robots with diverse functions. The set is composed of sensors and accessories, such as gears, belts, shafts, wheels and connectors, that are useful for building robotic structures [26]. The sensors include touch, sound, light, infrared, among others. The central component is the EV3 brick, which is a computer that works as the robot's brain by controlling the sensors, movements, functions and motors [27].

In the current research, a robot known as the PvBOT is built and programmed to teach children with ASD the concept of place values, as shown in Fig. 1. The PvBOT moves from one number to another and pronounces each number according to the place values arranged on the activity board, as shown in Fig. 2. The process of developing the PvBOT included assembling and building the structure of the PvBOT and coding the program to detect arranged numbers and their place values.

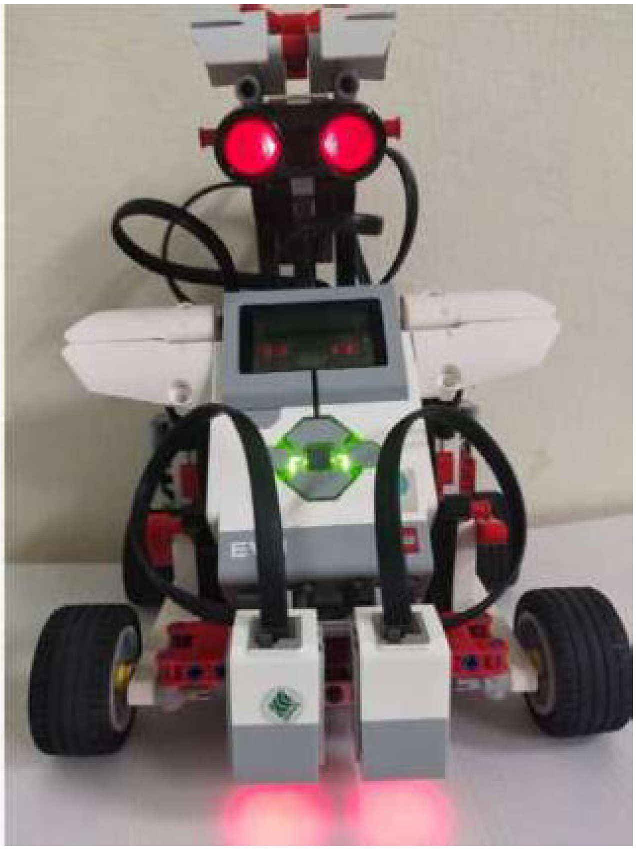

FIGURE 1. PvBOT - a LEGO Mindstorms EV3 robot for teaching place values.

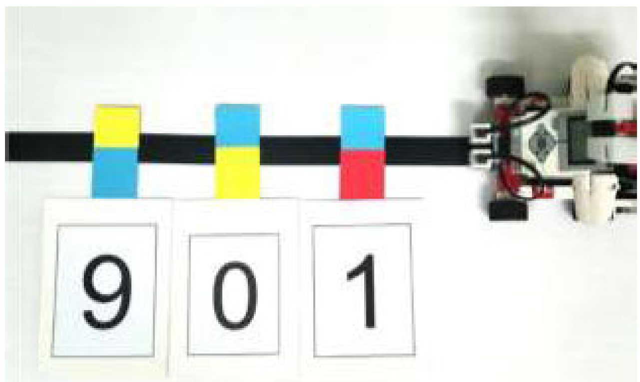

FIGURE 2. PvBOT and the activity board used for teaching place values.

Researchers started investigating the efficacy of robots in teaching autistic children decades ago [28]. This interest derives from the characteristics of a robot that promote the interest of children with ASD, which in turn guides them to focus on learning [29]–[31]. In this way, robots represent a concrete scaffold for cognition in learning that includes improving children's social skills [29]. The results of previous studies have indicated that there is 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 communicated with each other, thus enhancing their social skills. Furthermore, robots have been utilized to deliver science, technology, engineering, and mathematics (STEM) education to children with ASD [30]. More specifically, robots have been beneficial in demonstrating the concepts of force, motion, direction and distance. In a recent study, LEGO EV3 Mindstorms was introduced to encourage children with ASD to be receptive to various sensory experiences [31], [32]. Overall, the results have shown positive outcomes, with robots proving to be effective tools capable of sustaining children's interest and engagement.

Based on these studies, an emerging and quite unexplored area with respect to the efficacy of the intervention of robotics in the teaching and learning of children with ASD should be investigated. This includes the results of interactions with robots, e.g., touching, approaching, watching from a distance, etc. References [33], [34], and whether the use of robotics has improved the cognitive abilities of children with ASD. Moreover, research should communicate the valuable experiences children with ASD garner through robotic interventions [19], [35], [36]. This includes the experience of being able to develop complex aspects of social interaction, such as eye contact, turn-taking, and purposive and imitative actions when learning through the use of AT, especially robots.

Results from recent studies suggest that robotics have the potential to become remarkable AT tools in many ways, including for teaching and learning among children with ASD. Accordingly, this study investigates and presents evidence that supports this notion. Consistent with this, the objectives of this study are to determine whether robots as AT tools can (i) profoundly increase the cognitive achievement of children with ASD and (ii) provide children with ASD valuable classroom learning experiences. Accordingly, this article addresses the following research questions:

1. Are robots, as AT tools, capable of enriching the cognitive abilities of children with ASD?
2. In what ways can robots, as AT tools, provide valuable classroom learning experiences for children with ASD?

II. THEORETICAL RATIONALE

The work of this current study is to highlight the importance of play in early childhood special education settings. This is in line with previous studies that posit that for children, play is correlated with the development of autism in areas such as cognition, language, and social skills [17]. This group of children can learn about themselves and their environment as well as develop cognitive, social, and perceptual skills through play activities. The potential for cognitive development is founded on the development attained when a child engages in social interactions, and the meanings of concepts and ideas are learned through informal ways that are more meaningful and that simply allow learning to happen.

This current study adopts the work of [19] as the underlying theoretical lens through which it views robotic interventions for children with ASD as a tool that allows learning to happen through play in the following ways:

1. Nonformal therapy and learning: Play scenarios are based on the concepts of nonformal therapy and learning methodology where learning emerges from play activities. Such scenarios offer resources for joyful experiences and expressive interactions in which the child is empowered to control feedback stimuli.

2. Integrated activities with motor manipulation: Play in the scenarios involves the integration of activities with motor manipulation that allows learning to occur. It is the play that allows low functioning children with autism to explore simple motor manipulation. The exploration and experiences associated with it allow learning to take place.

3. Supporting autism in the early years: Support during childhood years is crucial for children with ASD. This support should address various areas of the child's development including personal, social, emotional, communication and language development.

4. Action and reinforcement cycle: Interactions with the environment provide stimuli in what can be viewed as a dyadic model. The interaction and stimuli influence and control the behavior of the child with ASD, a process that helps enrich the child's development.

These underlying theoretical perspectives of [19] are adapted in the robotic intervention work of this current study. The method employed is elaborated in the next section.

III. METHODS

A. PARTICIPANTS

The participants in this study are Malaysian students from a special education integrated school located in Ipoh Perak, which is north of the peninsula of Malaysia. The school is one of the oldest government-funded special education and inclusive schools in Malaysia. Eight participants were selected, and consent was obtained from their guardians/parents and the school headmistress. The study was authorized by the Perak State Special Education Division (PSSED). The participants were children who have been diagnosed with ASD as verified by medical experts and the PSSED authorities in a clinical setting that is not part of this study. Malaysian Ministry of Education (MOE) policy states that all students with ASD are to be diagnosed in a clinical setting by medical experts before entering any special education integrated schools in Malaysia. Data and profiles for each student are maintained by the school and the PSSED.

All procedures involving students with ASD participating in or involved with this research were conducted in accordance with the ethical standards outlined by the education policy research and development division of the Malaysian MOE. The ethics policy application was submitted through an online system, and approval was received from the Malaysian MOE before the research was conducted. The ethics approval was distributed to the participants' parents/guardians and teachers and to the school.

The inclusion criteria for participation were as follows: (1) be a Year 4 student registered in the special education program and the integrated school system of Malaysia, (2) be diagnosed with verbal autism, (3) be able to care for oneself without the need of a carer, (4) have no serious physical defects, (5) have no unusual behavioral problems such as hyperactivity (uncontrollable) or violent or severe mental issues, and (6) have no internal ailments such as chronic seizures, heart failure, etc. Both males and females were eligible to participate in the study.

Although the participants were Year 4 students, their ages varied, ranging from 10 to 13 years. This variation is because student class placement is in accordance with the rules of the Malaysian education regulations for special education children. More specifically, a student who has been identified by a medical expert as having a learning disability will undergo a probationary period of no more than three months. Within those three months, special education teachers are responsible for carrying out screenings of the child's learning problems and intellectual functioning. The filtering process is performed using a guidebook provided by the Special Education Department of the Malaysian MOE. In the guidebook, there are instruments for the special education placement of students with learning disabilities based on the assessment of five components, namely, the child's ability to self-manage, behave appropriately, manipulate objects, communicate effectively using the Malay language, and perform specific mathematical tasks. Based on these assessments, the student is then placed in the appropriate classes in the special education program of the integrated school and monitored for progression and development.

B. ROBOTIC PLATFORM AND PROCEDURES

In this study, we created the PvBOT using LEGO Mindstorms EV3 as shown in Fig. 1. The PvBOT is 22.5 cm tall and 17.5 cm wide. It is a mechanoid robot that often attracts children's curiosity. The mechanoid was chosen over humanoid robots to prevent fear among children with ASD. The PvBOT makes very little noise, and the utterances it generates are not distressing to children. It is important to note that the PvBOT teaches about place values repetitively in the Bahasa Malaysia language. The PvBOT is programmed to perform and teach mathematical place values as presented in Fig. 3 and as explained herein

1) THREE-DIGIT PLACE VALUE STEPS (HUNDREDS)

1) The PvBOT begins by moving in a straight line following the black path.
2) The sensor will detect the first number and its place value, and the PvBOT utters the number followed by the place value, "ones".
3) The sensor then detects the second number and its place value, and the PvBOT utters the number followed by the place value, "tens".

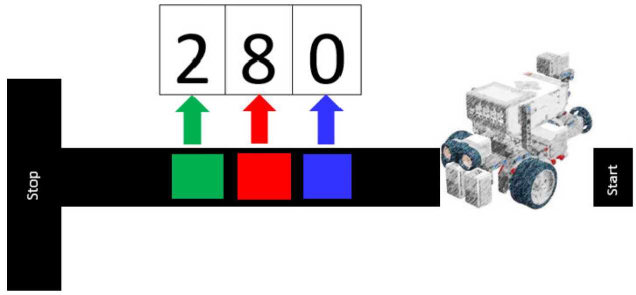

FIGURE 3. Setup of the PvBOT during the experiment.

4) The sensor then detects the third number and its place value, and the PvBOT utters the number followed by the place value, "hundreds".
5) Finally, the PvBOT = utters all the numbers in words and stops.

2) TWO-DIGIT PLACE VALUE (TENS)

1) Perform steps 1, 2, 3, and 5 from the Three-Digit Place Value steps.

3) ONE-DIGIT PLACE VALUE (ONES)

1) Perform steps 1, 2, and 5 from the Three-Digit Place Value steps

Referring to Fig. 3, the PvBOT moves on the activity board from 'start' to 'stop' and senses the number placed in each place value box. Each card has a number written on it. The child can freely pick, move, and place any cards on the place value boxes, i.e., ones, tens, and hundreds. Once they click the start button on the PvBOT, it starts to move from the one's box to the ten's box and finally to the hundred's box. The PvBOT reads the number and the place values. For instance, as shown in Fig. 3, when a child chooses three cards '2,' '8,' and '0' and places them in that order on the activity mat, the PvBOT will say "0-ones, 8-tens and 2-hundreds." Finally, the PvBOT will say, "two-hundred and eighty." The child can then change the numbered cards and place them in any of the place value boxes.

The PvBOT can move in both directions, i.e., ones-tens-hundreds or hundreds-tens-ones, depending on where it is initially placed. Referring to Fig. 3, it is suggested that the PvBOT be placed in the 'Start' area to prevent confusion. A child is expected to focus on the cards and listen to the uttered numbers and their place values. The total movement of the PvBOT to complete one activity takes between 8 and 30 seconds. The PvBOT and the activity that comes with it encourages the children to be active and focused during the lesson. Each child is given the opportunity to learn from the PvBOT for 15 minutes with minimal guidance from teachers while being observed by a researcher who observes the child in an unobstructed manner and assists when needed.

For this study, two modules were prepared. The learning outcome of Module 1 is to understand ones and tens place values. For Module 2, the learning outcome is to understand the hundreds place value. Both modules are presented in two different settings: (1) traditional learning environment

TABLE 1. Children participants.

Student	Gender	Age	Race	Group	Diagnosis
A	Female	10	Malay	1	Mild Autism Spectrum Disorder (ASD)
B	Female	11	Malay	1	Mild Autism Spectrum Disorder (ASD)
C	Male	13	Chinese	1	Moderate Autism Spectrum Disorder (ASD)
D	Male	13	Malay	1	Mild Autism Spectrum Disorder (ASD)
E	Female	11	Malay	2	Mild Autism Spectrum Disorder (ASD)
F	Female	13	Chinese	2	Mild Autism Spectrum Disorder (ASD)
G	Male	11	Malay	2	Moderate Autism Spectrum Disorder (ASD)
H	Male	10	Malay	2	Mild Autism Spectrum Disorder (ASD)

conducted by a teacher with a whiteboard and markers and (2) a learning environment with AT using the PvBOT.

In this study, children were divided into two groups, i.e., Group 1 and Group 2. Each group consisted of four children, as shown in Table 1. They were then given the opportunity to experience both traditional learning and learning from the PvBOT as an AT tool. Group 1 received traditional learning for Module 1 and training from the PvBOT for Module 2. Conversely, Group 2 experienced learning from the PvBOT for Module 1 and traditional learning for Module 2. Fig. 4 provides an example of how the participants typically behaved while learning with the PvBOT. All pictures are published in accordance to the ethical standards outlined by the education policy research and development division of the Malaysian MOE.

C. ASSESSMENTS

In collaboration with two special education teachers, assessment questions were developed for students to answer after they had undergone the two learning modules. The assessments were created to measure growth in cognitive abilities after learning about place values, and the results were used to compare growth in cognitive abilities after undergoing traditional learning and learning from the PvBOT as an AT tool. Two assessments were created. The first assessment tested children's understanding of ones and tens place values, and the second assessment tested the understanding of the hundreds place value. Both were individual assessments and were paper and pencil based. Children sat for the assessment after a 10-minute break following the learning session. Both groups of children sat for the same assessments, as it was irrelevant whether the group of children received the traditional teaching or the PvBOT instruction. The sample assessment instrument is presented in Fig. 5 and has been translated from Bahasa Malaysia to the English language.

The assessment was designed purposefully to be simple in nature. The reason for such a design is threefold:

FIGURE 4. Learning with assistive technology, the PvBOT.

NAME : ____________________
YEAR : ____________________
DATE OF ASSESSMENT : ____________________
TEACHER'S NAME : ____________________

Match the underlined numbers with the correct place values:

1	14	Tens
2	30	Ones
3	9	Tens
4	56	Ones
5	88	Tens

/10 points

FIGURE 5. Template to describe assessment questions after each learning session.

(1) to ensure that children with ASD can perform the assessment independently with minimal guidance, (2) to relieve teachers of the responsibility for refining and/or providing one-to-one instructions to each student when completing the test, and (3) to serve an individualized instruction that matches the IQ level of the selected children. The aim of the assessment was to have operationally defined variables that allow direct observation and empirical summary, i.e., the number of correct answers.

D. DATA COLLECTION AND ANALYSIS

This study employed a single-case research design, which is considered highly appropriate for special education research. Two categories of data collection and analyses were conducted: (i) quantitative analysis that was numerical and statistically based on student assessment scores and (ii) qualitative analysis that was descriptive and based on interview data.

This study has extracted quantitative data to obtain answers to the first research question, which was to find evidence for how robots, when used as AT tools, can profoundly impact the degree of cognitive ability in children with ASD. At every stage, the students' assessment scores were charted during both the traditional learning process and the robotic intervention learning process. Accordingly, this strategy yielded concrete results regarding the efficacy of robots as AT tools on students' cognitive abilities in grasping knowledge on place values.

Additionally, this study collected qualitative interview data to understand how the PvBOT as an AT tool was able to provide valuable classroom learning experiences for children with ASD. Six teachers were interviewed after all lessons and assessments were completed. Each participating teacher was asked three open-ended interview questions.

1) From yours observations during the case study conducted, what are the positive aspects of using the PvBOT to teach the concept of place value?
2) From your observations during the case study conducted, what are the negative aspects of using the PvBOT to teach the concept of place value?
3) Please share any other thoughts or input based on your observations throughout the sessions?

Anecdotes were received from each participating teacher that illustrate the story of each child as they learned a specific concept using the PvBOT as an AT tool and as they learned via a traditional teaching strategy. Based on the teachers' comments and stories, reports were then prepared that summarized the children's engagement and learning experiences with the robot (i.e., PvBOT) as an AT tool.

IV. RESULTS

A. DEMOGRAPHIC DATA

Participants in this study included eight children (n = 8) with mild or moderate autism (four males and four females). One may argue that fewer females in schools are diagnosed with ASD [37]. For this case study, however, there were equal numbers of male and female participants. This is because the participants were not randomly selected but rather chosen because they met the inclusion criteria established by the researchers (see Methods subsection A). There may also be concern regarding the reliability of the results given the limited number of participants. While single-subject designs may involve only one participant, they typically include multiple participants, i.e., between 3 and 8 in a single study. It is important to note that this research was experimental in nature and that its purpose was to document the effect within and between subjects to control for major threats to internal validity. Accordingly, a systematic replication was required to enhance the study's external validity. The control group design, in turn, was used to further demonstrate the external validity of the findings. Furthermore, it is expected that the generality of this type of research will be established not by a single study but through systematic replication across multiple studies conducted in multiple locations and across multiple researchers.

The demographic details of the children are presented in Table 1. The participants are anonymized and identified by the letters A to H in Table 1. Consent was obtained from the guardians/parents of all participating children, and authorization for the study was granted by the school and the PSSED. It must be noted that these students were one to three years behind children with typical development, and their full-scale intelligent quotients (FSIQ) ranged between 40 and 54. Thus, they were categorized as moderately impaired. Finally, these students had not played with any robots or experienced any robotic intervention, as such teaching methods and interventions were not part of the school's teaching methodology.

Face-to-face interviews were conducted with six special education teachers and the principal/headmistress of the school. These are special education teachers who work and teach at the same school the children participants attend. All interview sessions were conducted at the school and were between 30 and 75 minutes long. Conducting these sessions in the same venue where the robotic intervention was conducted created a familiar atmosphere where the participants could point to a chart or a book during the session. The interviews were conducted in a meeting room, and a video camera was used to record the session with the consent of the teachers. The PvBOT was also brought into the room so teachers could touch and point to certain aspects of the tool during the interview session. Student assessment answer sheets were also available in the room for reference. Table 2 presents the characteristics of the six teachers interviewed. Their average work experience in any special education integrated school was eight years.

B. MAIN DATA

The two groups of students completed both the traditional learning and the PvBOT learning without any major interruptions or distress. At the beginning of the robotic intervention, the teacher explained how to operate the PvBOT, as shown in Fig. 6. The teacher then performed

TABLE 2. Interview participants demographic profiles.

Teacher	Gender	Age	Race	Role	Teaching Experience
1	Female	33	Malay	Special Education Teacher	7 years
2	Female	51	Malay	Special Education Teacher, Principal	15 years
3	Male	37	Malay	Special Education Teacher	10 years
4	Male	35	Malay	Special Education Teacher	9 years
5	Female	29	Malay	Special Education Teacher	4 years
6	Female	30	Chinese	Special Education Teacher	5 years

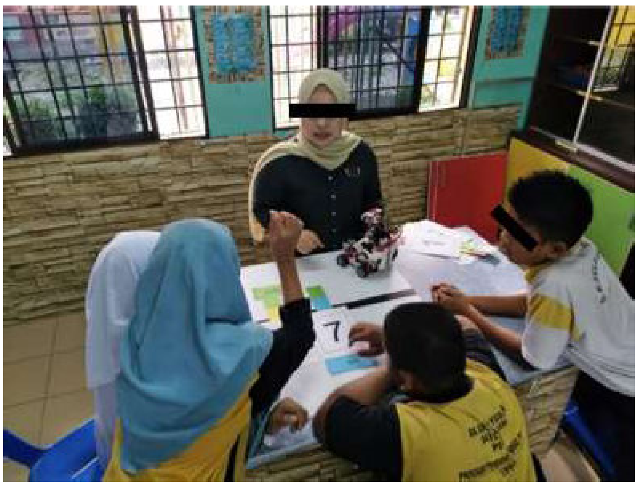

FIGURE 6. Teacher giving a step-by-step explanation and demonstration of how to operate the PvBOT.

a step-by-step demonstration on how to operate the PvBOT with the activity board, cards and place value boxes. Each student was then given the opportunity to learn using the PvBOT. During traditional learning, the teacher explained about place value using the whiteboard and drawings. This we followed by giving each child place value cards children, which were then explained to the students. At the end of each lesson, the children sat for a 15-minute assessment. As previously mentioned, both groups of children sat for the same assessments, i.e., it was irrelevant whether the children experienced traditional learning or learned via the PvBOT).

TABLE 3. Students' assessments score.

First Module (One- and Two-Digit Place Value)				Second Module (Three-Digit Place Value)			
Traditional Learning		Robot as an Assistive Technology		Traditional Learning		Robot as an Assistive Technology	
Group 1 students	Score	Group 2 Students	Score	Group 2 Students	Score	Group 1 Students	Score
A	55%	A	85%	A	65%	A	80%
B	45%	B	75%	B	45%	B	100%
C	65%	C	95%	C	65%	C	95%
D	75%	D	100%	D	75%	D	100%
Mean Score	**60%**	**Mean Score**	**88.75 %**	**Mean Score**	**62.5 %**	**Mean Score**	**93.75 %**

TABLE 4. Results of independent sample t-test on assessment scores.

	Robotics Intervention	Traditional Learning
Mean	91.25	61.25
Standard Deviation	9.91	11.88
Observations	8	8
P (T<=t) two-tail	0.00013	

The assessment results collected from both groups are presented in Table 3. For the first module, the mean score for Group 1, which received traditional learning, was 60, while Group 2, which was taught via the PvBOT, achieved a mean score of 88.75. With respect to the scores for Module 2 in Table 3, the result for Group 1, which was taught using the PvBOT, exhibited a mean score of 93.75, whereas Group 2, which received traditional learning, had a mean score of 62.50. The t-test statistical analyses were performed based on the assessment scores recorded for both groups.

Table 4 reports the results of the independent sample t-test. Thus, cognitive ability achievement based on traditional learning and robotic intervention can be compared. The mean score for robotic learning is 91.25, while the mean score for traditional learning is 61.25. This implies that students better comprehend the concept of place value when they have the opportunity to learn from the PvBOT. Moreover, the standard deviations for robotic learning and traditional learning were 9.91 and 11.88, respectively, indicating that robotic learning exhibited a smaller standard deviation than did traditional learning. This result implies that the scores of students engaged in robotic learning were nearer to the mean score and were more consistent than the scores of students engaged in traditional learning, in which the students' performances exhibited greater variance. This is supported by the coefficient of variation, where robotic learning (10.86%) exhibited a consistent score when compared to traditional learning (19.40%). Furthermore, the p-value for a two-tailed independent sample t-test was less than 0.05, which indicates that there is a significant difference in the mean score between robotic learning and traditional learning. Therefore, it is evident that robotic learning had a more consistent performance score than traditional learning, indicating a better acceptance by every child with ASD and thus ensuring that no child is left behind. Based on these results, this study posits that robots are a highly efficacious AT tool that, when compared to traditional learning, improve the cognitive abilities of children with ASD.

The interviews with the six special education teachers revealed that robotics learning resulted in four valuable classroom learning experiences. Specifically, robotics learning (1) promoted student interest in learning and increased student engagement in classroom activities; (2) attracted the attention of students and encouraged them to focus on engaging in classroom activities; (3) triggered interactions and communication among the child, the robot and another person; and (4) created an atmosphere of joy and fun while engaging in classroom learning activities.

1) INTEREST AND ENGAGEMENT

First, the special needs teachers emphasized that the introduction of the PvBOT enhanced student interest in learning and increased student engagement in classroom activities. The PvBOT served as an inviting assistant that welcomed children to learn. As such, the PvBOT was capable of removing barriers that normally prevent these children from feeling free and behaving in certain desired ways in class. One of the special needs teachers pointed out that *"Maybe because the PvBOT is not emotional like anyone of us, and the PvBOT will never be angry, it can repeat the place value like a hundred times! Probably because the PvBOT never gets angry and is super patient with children, it makes them feel safe and they are attracted to it"* Teacher 2. Another special education teacher stated that *"These kids often get distracted easily... the PvBOT stimulates their interest. They will come in front of the class to look at the PvBOT, touch it, hold it, and play with it without being asked! In normal [traditional] classes, they often sit in the back, look outside the class and don't bother to learn,"* Teacher 5.

From their perspective, the PvBOT stimulates children with ASD to play and learn, which indirectly increases their interest and engagement in learning. They also noted that the PvBOT is capable of attracting children's curiosity and inducing them to start doing things that indirectly teach them the lesson. As one of the special needs teachers highlighted, *"The PvBOT was able to stimulate student interest to pick cards and put them in the boxes, and they were excited to know the numbers and watch where it [the* PvBOT] *moves! The movement, the colors, the LEGO robot itself attract their interest and naturally they learn without being forced,"* Teacher 1.

Based on this evidence, this study asserts that the robot as an AT tool is capable of gaining students' interest toward learning and increasing their level of engagement in classroom activities, which is consistent with previous works that have found that nonhumanoid robots enhance children's attentive skills and promote their engagement in assigned tasks. Thus, it is evident that robots provide a valuable classroom experience for children with ASD that eventually can help each of them reach their full potential.

2) ATTENTION FOCUS

Second, it was determined that the PvBOT is a helpful AT tool in that it motivates children with ASD to pay attention and focus for a longer time period when engaging in classroom activities. They further emphasized that the PvBOT could be used as a classroom tool to attract the attention of the students. This was the case on many occasions, as the PvBOT was able to induce the children to focus on the learning of place values. As one of the teachers mentioned, *"In my class, it was so difficult to get them to listen to me for even a mere five minutes! But with the PvBOT, they seemed to be listening and focusing for almost 20 minutes!"* Teacher 1. Hence, it is evident that the children's attention span was extended when the PvBOT was teaching the student compared to when the teacher was instructing the student. This is critical, as focus is the key to learning and developing cognitive abilities. The same teacher stated, *"Without focus, it is difficult for learning to occur. That is why it is so important that we motivate them to focus on what is being conveyed and the PvBOT seems to be very good at doing that,"* Teacher 1. In other words, the PvBOT motivates the children to pay attention and focus on understanding the content. Once students are able to focus on the content, they are better able to comprehend the subject matter, and this is when learning occurs. As elaborated by a teacher, *"With the robot, children become immersed in what it [the robot] does and what it says, and thus, they [the children] come forward, they see, they touch, they listen and they even giggle. They stand and enjoy the moment of learning and even imitate what the robot says, i.e., the number and place values. The children are immersed by the robot and eventually they learn about place values"* Teacher 3.

This finding is consistent with the theoretical lens which asserts that play-based learning (i.e., robots for this study) allows children with ASD to explore. It is through the exploration process that the children become more focused on and immersed in the content, which then contributes to their learning. Based on the evidence presented herein, this study emphasizes that the use of the PvBOT is a helpful AT tool that holds the attention of the children and keeps them focused on the learning activities during the lessons. This supports the capability of robots to be an efficacious AT tool that creates an immersive classroom environment that eventually allows learning to occur.

3) INTERACTION AND COMMUNICATION

Third, this study has determined that the PvBOT could be an AT tool that prompts interactions and communications among children with ASD. One of the special education teachers noted that the PvBOT encourages contact, interaction and communication to among the child, the robot and another person. These scenarios were witnessed by the teachers throughout the study without them coercing the children to communicate. Teachers were surprised to witness many occasions where these children communicated and interacted with another child and with the researcher. The teachers also commented that the PvBOT could be a mediator or object that promotes communication and interactions with one another. One of the special education teachers commented, "*I was surprised to see B [name omitted], who hardly talks to others, be excited to show what he could do with the PvBOT to his friends. He even waited for his turn and upon completing the activity he gave the opportunity to his friend and started to help him with the robot. I find it very interesting to see these types of skill improvements happening among my children in class,*" Teacher 4.

The evidence from this study indicates that the teachers acknowledged the valuable impact of robotic learning and believed that it can be an effective medium that encourages children with ASD to communicate with and reach out to others. Previous works have also found that robots can serve as social mediators, a finding that is consistent with the theoretical lens that interpreted this interaction as a dyadic model that helps enrich a child's development. Accordingly, we are comfortable claiming that robots have the ability to be effective AT tools that promote classroom interactions that are essential for shared educational activities. In the long run, this may encourage better communication among children with ASD and allow them to feel more relaxed and calmer in the classroom environment.

4) HAPPINESS AND FUN

The results further indicate that the majority of teachers agreed that the introduction of the PvBOT created an atmosphere of happiness and fun in the classroom. Children found it interesting to play and interact with the PvBOT while simultaneously learning. The classroom environment changed from one where children sit passively at their desks to one where they play a more active role in their learning. As one of the teachers stated, *"The kids were enjoying themselves and remained standing and some were clapping their hands. They love seeing the robot move, turn and talk. They also love the colorful cards and the activity board. They find it entertaining. They keep asking when the robot is coming again"* Teacher 6. Robotic intervention has allowed learning to occur in a play mode that creates an atmosphere of entertainment for the child. Consistent with this premise, the teachers stressed that it is important to create a fun and happy environment for this group of children given that they can learn only in nonstressful situations. As mentioned by one of the teachers, *"If they are throwing tantrums and are in bad moods, we have to control the situation. It interrupts the whole class and learning cannot happen. The PvBOT can be of assistance in such situations. It [the robot] can make my students feel happy and excited to learn"* Teacher 2.

Based on the evidence collected, this study asserts that robots such as the PvBOT have the potential to serve as AT tools that make learning exciting and fun for children with autism. These elements are crucial to ensure that these children are engaged in classroom activities, as they create an enjoyable and interesting classroom learning environment that may escalate students' interest in learning. This premise is in line with the theoretical lens of play-based learning, which highlights that play activities offer joyful experiences that empower the child and promote nonformal learning.

5) AN ASSISTIVE TECHNOLOGY

Finally, all the teachers strongly emphasized that the robot was a great AT tool that intensifies their teaching delivery in the classroom. In addition to students having benefitted from robotic learning in remarkable ways, the teachers also found that the PvBOT alleviated some of their challenges in teaching. For example, the majority of the teachers agreed that the PvBOT was of great assistance in repeating content. As one teacher stated, *"PvBOT can repeat the numbers and sentences again and again to all of them [the students with ASD]. That is like telling them the same thing sixty times, over and over again. I could not be doing that every day. So, I thank the PvBOT for doing that for me!*" Teacher 6.

It is further highlighted that a robot is not intended to replace teachers in classrooms. Robots are man-made machines that can support and challenge students in current resource-limited educational environments. With assistance from robots, teachers can spend more time providing comprehensive attention, empathic care, and special attention to those in need. As stressed by the headmistress, "*They [robots] will be valuable as assistants to teachers but not replace the teachers. A teacher is needed in class to organize the lesson, look after the kids, take care of them, control their emotions, provide extra assistance when needed, react when there is any emergency situation and to handle many more duties that a robot cannot do.*" Another work also highlighted that the teacher's presence is necessary to monitor and respond to challenging situations such as students' frustrations and distressing emotional states. Thus, it is concluded that a robot is a great AT tool for teaching, but it is not intended to replace the teacher, who is needed to educate and provide rewarding educational experiences for children.

V. DISCUSSION AND CONCLUSION

The aim of this study was twofold. First, we investigated whether robots as AT tools can profoundly enhance the knowledge and cognitive abilities of children with ASD. The mean score assessment results suggest that the robotics intervention has a greater impact on children's cognitive development than traditional teaching/learning. Furthermore, the results of the independent sample t-test analyses indicate that the robotics intervention performs better than the traditional ways of learning. Similarly, the standard deviation of robotics learning is lower than that of traditional learning, suggesting that the performance of the robotics intervention is closer to the mean value. Conversely, traditional learning has a higher standard deviation level, which represents a greater dispersion of student performance values. Furthermore, the p-value for the two-tailed independent sample t-test is less than 0.05 and is accepted as significant in determining that the mean values of both groups are not statistically equal. Hence, based on these results, this study asserts that robots as AT tools have a profound impact on developing the cognitive abilities of children with ASD. This is consistent with other works that have identified the potential of robots as tools that attract and retain the attention of children with ASD and ultimately promote cognitive development [12], [13], [38]–[40].

Second, another goal of this study was to gather insight into how robots, as AT tools, provide valuable learning experiences to children with ASD. The results from interviews with special education teachers highlighted four remarkable learning experiences created in classrooms through robotic interventions: (1) increase student interest in learning and student engagement in classroom activities, (2) attract and retain student attention and focus on classroom activities, (3) trigger interactions and communication among the child, the robot and another person, and (4) create an element of happiness, fun and leisure as children engage in learning activities in the classroom. These learning experiences were defined based on the teachers' vast experiences in educating and scaffolding the learning of children with ASD. It is claimed that the functions of the robot bring added value to the classroom and play a supporting role by providing rewarding educational experiences.

The strength of this study is that it provides evidence of how robots can be leveraged as AT learning tools in classrooms for children with ASD through the theoretical lens of play-based education. AT embraces a wide range of devices, among which, as evidenced in this work, the robot is one. This study also demonstrated the efficacy of robots as AT, particularly in special education classes and inclusive school systems. This includes the support that robots can provide children with ASD by allowing for repetitive delivery and engagement in routine tasks and offering personalized teaching. That said, the robot not only benefits children with ASD but also is used as a teaching aid by special education teachers. In the broadest sense, robots have the potential to become part of the infrastructure of special education programs and inclusive school systems just as paper, whiteboards, and markers are.

The single case study evidence presented herein has the potential to make a meaningful contribution to the body of literature on special education teaching and learning, particularly for children with ASD. Furthermore, our findings promote understanding and highlight ways that special education curriculum can adopt the notion of play-based learning through robotic intervention, thus supporting the theoretical lens in the following four ways: (1) providing nonformal therapy and learning in classrooms, (2) enabling the integration of activities with active learning, (3) offering a simple curriculum design focused on the early stages of autism, and (4) using AT to conduct activities and reinforce the child's learning development.

This study also indicates that because robots have limitations, they are best used as AT tools in classrooms. This recommendation is consistent with the work of [15] who concluded that robots should serve as additional tools under the control of professionals rather than serving as the main actor in any situation. Thus, consistent with previous works, it is predicted that robots will continue to play a significant role in classrooms for children with ASD but that they will never replace classroom teachers.

One of the limitations of this study is the price of LEGO Mindstorms EV3, as not every parent or special education and integrated school can afford to purchase LEGO sets. This applies to the majority of other types of robotic tools as well, such as the NAO. However, it is hoped that one complete set of LEGO Mindstorms EV3 could be used for many teaching and learning modules that cover a wide range of topics. Teachers, as well as parents, could then assemble and download the codes for the robot to deliver various modules guided by the instructions.

Moreover, the potential that was identified using LEGO Mindstorms EV3 could also be applied to many other AT robotic tools. [15] highlight that often, on an abstract level, many robots have similar characteristics. For instance, other robots such, as the NAO as presented in [24], and [41] have demonstrated that they provide consistent interaction, and in this way, they become an additional support for teachers and therapists.

While this study was purposefully simple in design, several other limitations must be mentioned and considered. Children were only given one session with the robot, and it lasted a short period of time. Sessions over longer time spans may offer additional insights. Moreover, the assessment conducted as part of this study examined only achievements in cognitive abilities. Future studies should include other variables that measure gaze, emotional state, number of communications, number of responses to robot's commands, and speed or promptness of responses to robot's instructions. On another note, this work was designed as a cross-sectional study, whereas data collected through a longitudinal study may offer different insights. While the current study provides data that suggests that children with ASD better understand the concept of numbers when robots are used to deliver the lessons than when traditional learning techniques are employed, this finding is not generalizable to other topics. Hence, future studies may conduct cross-topic analyses that include other topics in mathematics as well as topics related to time and recycling skills. Furthermore, our study employed a relatively small number of participants ($n = 8$). A larger sample size may provide more interesting results. Finally, this study offers a novel comparison between traditional learning and a robotics intervention in the classroom, suggesting that robots as AT have a positive impact on learning among children with ASD. Nonetheless, further investigations within a controlled clinical setting may be beneficial.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Malaysian Ministry of Higher Education (MOHE) for the research Grant and Support given throughout the project. The authors thank Nazeffa Syaza Suhaimy for her assistance in data collection, analyses, and study administration. This article was presented at the Final Year Project Presentation. Nurshazlyn Mohd Aszemi has given talks based on this study since then. The authors also thank the Universiti Teknologi PETRONAS and the Perak State Special Education Division (PSSED) for their support throughout this project. The views expressed are those of the author(s) and not necessarily those of the Ministry of Education, Malaysia.

REFERENCES

[1] World Health Organization. (2019). *Autism Spectrum Disorders*. Accessed: Apr. 8, 2020. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/autism-spectrum-disorders. [Accessed: 08-Apr-2020].

[2] B. Weikle and A. Hadadian, "Can assistive technology help us to not leave any child behind?" *Preventing School Failure: Alternative Edu. Children Youth*, vol. 47, no. 4, pp. 181–186, Jan. 2003.

[3] R. Y. Cai and A. L. Richdale, "Educational experiences and needs of higher education students with autism spectrum disorder," *J. Autism Develop. Disorders*, vol. 46, no. 1, pp. 31–41, Jan. 2016.

[4] W. Abdallah, F. Vella, N. Vigouroux, A. Van den Bossche, and T. Val, "A collaborative talking assistive technology for people with autism spectrum disorders," in *Proc. Int. Conf. Hum.-Comput. Interact.*, 2019, pp. 3–12.

[5] S. J. O'Neill, S. Smyth, A. Smeaton, and N. E. O'Connor, "Assistive technology: Understanding the needs and experiences of individuals with autism spectrum disorder and/or intellectual disability in Ireland and the UK," Assistive Technol., Milton Park, U.K., Tech. Rep., Jan. 2019, pp. 1–9.

[6] A. R. Beck and C. M. Pirovano, "Facilitated communicators' performance on a task of receptive language," *J. Autism Develop. Disorders*, vol. 26, no. 5, pp. 497–512, Oct. 1996.

[7] R. B. Lewis, "Assistive technology and learning disabilities: Today's realities and tomorrow's promises," *J. Learn. Disabilities*, vol. 31, no. 1, pp. 16–26, Jan. 1998.

[8] D. C. Duhaney and L. M. G. Duhaney, "Assistive technology: Meeting the needs of learners with disabilities," *Int. J. Instructional Media*, vol. 27, no. 4, pp. 393–401, 2000.

[9] C. Lankshear and M. Knobel, "New technologies in early childhood literacy research: A review of research," *J. Early Childhood Literacy*, vol. 3, no. 1, pp. 59–82, Apr. 2003.

[10] S. Alper and S. Raharinirina, "Assistive technology for individuals with disabilities: A review and synthesis of the literature," *J. Special Edu. Technol.*, vol. 21, no. 2, pp. 47–64, Mar. 2006.

[11] G. Alnahdi, "Assistive technology in special education and the universal design for learning," *Turkish Online J. Educ. Technol.*, vol. 13, no. 2, pp. 18–23, 2014.

[12] C. A. G. J. Huijnen, M. A. S. Lexis, R. Jansens, and L. P. de Witte, "How to implement robots in interventions for children with autism? A co-creation study involving people with autism, parents and professionals," *J. Autism Develop. Disorders*, vol. 47, no. 10, pp. 3079–3096, Oct. 2017.

[13] S. Boucenna, A. Narzisi, E. Tilmont, F. Muratori, G. Pioggia, D. Cohen, and M. Chetouani, "Interactive technologies for autistic children: A review," *Cognit. Comput.*, vol. 6, no. 4, pp. 722–740, Dec. 2014.

[14] B. Burne, V. Knafelc, M. Melonis, and P. C. Heyn, "The use and application of assistive technology to promote literacy in early childhood: A systematic review," *Disab. Rehabil., Assistive Technol.*, vol. 6, no. 3, pp. 207–213, May 2011.

[15] C. A. G. J. Huijnen, M. A. S. Lexis, R. Jansens, and L. P. de Witte, "Roles, strengths and challenges of using robots in interventions for children with autism spectrum disorder (ASD)," *J. Autism Develop. Disorders*, vol. 49, no. 1, pp. 11–21, Jan. 2019.

[16] X. Hu, Q. Zheng, and G. T. Lee, "Using peer-mediated LEGO play intervention to improve social interactions for chinese children with autism in an inclusive setting," *J. Autism Develop. Disorders*, vol. 48, no. 7, pp. 2444–2457, Jul. 2018.

[17] B. Scassellati, H. Admoni, and M. Matarić, "Robots for use in autism research," *Annu. Rev. Biomed. Eng.*, vol. 14, no. 1, pp. 275–294, Aug. 2012.

[18] K. Shinohara and J. O. Wobbrock, "In the shadow of misperception," in *Proc. Annu. Conf. Human Factors Comput. Syst. (CHI)*, 2011, pp. 705–714.

[19] H. Kumazaki, T. Muramatsu, Y. Yoshikawa, Y. Yoshimura, T. Ikeda, C. Hasegawa, D. N. Saito, J. Shimaya, H. Ishiguro, M. Mimura, and M. Kikuchi, "Brief report: A novel system to evaluate autism spectrum disorders using two humanoid robots," *J. Autism Develop. Disorders*, vol. 49, no. 4, pp. 1709–1716, Apr. 2019.

[20] G. E. Lancioni, N. N. Singh, M. F. O'Reilly, and G. Alberti, "Assistive technology to support communication in individuals with neurodevelopmental disorders," *Current Develop. Disorders Rep.*, vol. 6, no. 3, pp. 126–130, Sep. 2019.

[21] T. Nordström, S. Nilsson, S. Gustafson, and I. Svensson, "Assistive technology applications for students with reading difficulties: Special education teachers' experiences and perceptions," *Disab. Rehabil., Assistive Technol.*, vol. 14, no. 8, pp. 798–808, Sep. 2018.

[22] P. Pennisi, "Autism and social robotics: A systematic review," in *Autism Research*, vol. 9, no. 2. Hoboken, NJ, USA: Wiley, Feb. 2016, pp. 165–183.

[23] L. B. Jackson, D. L. Ryndak, and M. L. Wehmeyer, "The dynamic relationship between context, curriculum, and student learning: A case for inclusive education as a research-based practice," *Res. Pract. for Persons Severe Disabilities*, vol. 34, no. 1, pp. 175–195, Dec. 2008.

[24] J. Kaur *et al.*, "Technical report autism spectrum disorder research in Malaysia," Inst. Public Health, Ministry Health Malaysia, Selangor, Malaysia, Tech. Rep. 1, 2015, pp. 1–125. [Online]. Available: https://www.researchgate.net/publication/304441543_TECHNICAL_REPORT_AUTISM_SPECTRUM_DISORDER_RESEARCH_IN_MALAYSIA

[25] N. I. Arshad *et al.*, "Analyzing the effectiveness of robotic intervention among autism children in learning mathematics," in *Proc. Special Educ. Int. Conf.*, 2019.

[26] H. Altin and M. Pedaste, "Learning approaches to applying robotics in science education," *J. Baltic Sci. Educ.*, vol. 12, no. 3, pp. 365–377, 2013.

[27] J. Chetty, "The notion of Lego Mindstorms as a powerful pedagogical tool: Scaffolding learners through computational thinking and computer programming," *Independ. J. Teach. Learn.*, vol. 10, no. 1, pp. 69–84, 2015.

[28] B. Caci, A. D'Amico, and M. Cardaci, "New frontiers for psychology and education: Robotics," *Psychol. Rep.*, vol. 94, no. 3, pp. 1372–1374, Jun. 2004.

[29] E. Valenzuela, A. Barco, and J. Albo-canals, "Learning social skills through LEGO-based social robots for children with autism spectrum disorder at CASPAN center in Panama," in *Proc. Conf. New Friends*, 2015. [Online]. Available: https://www.semanticscholar.org/paper/Learning-Social-Skills-through-LEGO-based-Social-at-Valenzuela-Barco/55651309b7a3e25e76a143d1266f5ab78feffa8e

[30] S. Disseler and G. Mirand, "Students with disabilities and LEGO education," *J. Edu. Hum. Develop.*, vol. 6, no. 3, pp. 38–52, 2017.

[31] H. Javed, R. Burns, M. Jeon, A. M. Howard, and C. H. Park, "An interactive robotic framework to facilitate sensory experiences for children with ASD," 2019, *arXiv:1901.00885*. [Online]. Available: http://arxiv.org/abs/1901.00885

[32] F. Soares, S. Silva, N. Gonçalves, J. Rodrigues, C. Santos, A. P. Pereira, and M. F. Moreira, "Robótica-Autismo project: Technology for autistic children," in *Proc. IEEE 3rd Portuguese Meeting Bioeng. (ENBENG)*, Feb. 2013, pp.1–4.

[33] K. Dautenhahn, "Design issues on interactive environments for children with autism," in *Proc. 3rd Int. Conf. Disabil. Irtual Real. Assoc. Technol.*, 2000, pp. 153–162.

[34] F. Michaud and C. Théberge-Turmel, "Mobile Robotic Toys and Autism," in *Socially Intelligent Agents*. Norwell, MA, USA: Kluwer, vol. 2006, pp. 125–132.

[35] H. Kumazaki, Z. Warren, A. Swanson, Y. Yoshikawa, Y. Matsumoto, Y. Yoshimura, J. Shimaya, H. Ishiguro, N. Sarkar, J. Wade, M. Mimura, Y. Minabe, and M. Kikuchi, "Brief report: Evaluating the utility of varied technological agents to elicit social attention from children with autism spectrum disorders," *J. Autism Develop. Disorders*, vol. 49, no. 4, pp. 1700–1708, Apr. 2019.

[36] J. Wainer, E. Ferrari, K. Dautenhahn, and B. Robins, "The effectiveness of using a robotics class to foster collaboration among groups of children with autism in an exploratory study," *Pers. Ubiquitous Comput.*, vol. 14, no. 5, pp. 445–455, Jul. 2010.
[37] P. Morales-Hidalgo, J. Roigé-Castellví, C. Hernández-Martínez, N. Voltas, and J. Canals, "Prevalence and characteristics of autism spectrum disorder among spanish school-age children," *J. Autism Develop. Disorders*, vol. 48, no. 9, pp. 3176–3190, Sep. 2018.
[38] T. Salter, I. Werry, and F. Michaud, "Going into the wild in child–robot interaction studies: issues in social robotic development," *Intell. Service Robot.*, vol. 1, no. 2, pp. 93–108, Apr. 2008.
[39] M. Begum, R. W. Serna, and H. A. Yanco, "Are robots ready to deliver autism interventions? A comprehensive review," *Int. J. Social Robot.*, vol. 8, no. 2, pp. 157–181, Apr. 2016.
[40] J.-J. Cabibihan, H. Javed, M. Ang, and S. M. Aljunied, "Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism," *Int. J. Social Robot.*, vol. 5, no. 4, pp. 593–618, Nov. 2013.
[41] A. Tapus, A. Peca, A. Aly, C. Pop, L. Jisa, S. Pintea, A. S. Rusu, and D. O. David, "Children with autism social engagement in interaction with nao, an imitative robot: A series of single case experiments," *Interact. Stud.*, vol. 13, no. 3, pp. 315–347, 2012.

NOREEN IZZA ARSHAD is currently an Associate Professor with the Universiti Teknologi PETRONAS, Malaysia. As a member of the Department of Computer and Information Sciences, she teaches and conducts research as part of the Positive Computing Research Center, Institute of Autonomous Systems. She has designed some methodologies, frameworks, tools and technologies for assisting society, that include robotics intervention, stuttering mobile applications, elderly monitoring systems, and content management systems for organizations among others. She is also with local and international counterparts that include the Royal Academy of Engineering, U.K., Oxford and Oxford's Global Innovation Consultancy, Oxford University, U.K., K-Perak Inc., and HUKM Hearing and Speech Clinic and many more. Her research interests include use of technologies, how this could lead to a better living and quality of life, and developing and promoting technologies as enablers to assist people in any aspect of life, including education, healthcare, and smart living.

AHMAD SOBRI HASHIM received the Bachelor of Technology (B.Tech.), the Master of Science (M.Sc.), and the Doctor of Philosophy (Ph.D.) degrees in information technology from the Universiti Teknologi PETRONAS (UTP).

He has been teaching, since 2014. He is currently a Senior Lecturer with the Computer and Information Sciences Department (CISD), Universiti Teknologi PETRONAS (UTP). He is passionate about teaching programming courses, including structured programming and web programming. He is supervising three Ph.D. students and two master's degree students. He has been published a number of research articles, since 2009, most of which are indexed by ISI and Scopus. He is concerned with society's well-being. His research and non-academic activities significantly contribute to society. He has completed one study, A Study on Acceptance of Mobile School System in Secondary Education and Walking into Autism's Minds, such as Theories, Conceptual Model, and Strategies for Inclusion. He has two on-going studies being conducted, such as (i) Teaching and Learning Structured Programming through Robotic Approach and (ii) Developing a Robotic Teaching and Learning Aid as an Effective Therapy for Autistic Children, Malaysia. He has gained significant achievements. His research interests include IT applications, e-systems, human-computer interactions, educational technologies, learning disabilities, and information systems.

Dr. Hashim received the gold medals from the Malaysia Technology Expo (MTE 2017), the International Competition and Exhibition on Computing Innovation (ICE-CInno 2016), the Pertandingan Rekacipta dan Inovasi Institusi Pengajian Tinggi Swasta (PERISTIS 2016), and the International Invention, Design and Articulation (i-IDeA 2016).

MAZEYANTI MOHD ARIFFIN received the bachelor's degree in information technology from the Universiti Teknologi PETRONAS, the master's degree in information technology from The University of Queensland, Australia, and the Ph.D. degree in information technology from the Universiti Teknologi PETRONAS.

She is currently a Senior Lecturer and a Researcher with the Universiti Teknologi PETRONAS. She is also with the Department of Computer and Information Sciences, as a Teacher, and a Researcher with the Positive Computing Research Center, Institute of Autonomous Systems. She has published articles on gamification, special education, and knowledge management. She has secured several grants related to dyscalculia, computer game studies, and the agriculture Internet of Things (IoT) and health. Her research interests include game-based learning and learning disorders, understanding the use of technologies, and how this use can improve people's lives and their quality of life. She has been a member of the International Association of Computer Science and Information Technology (IACSIT), since 2009. She has also been a part of the Malaysia Board of Technologist (MBOT), since 2018.

NURSHAZLYN MOHD ASZEMI received the Bachelor of Technology (B.Tech.) degree in business information systems (knowledge management) and the Master of Science (M.Sc.) degree in information technology from the Universiti Teknologi PETRONAS, Malaysia. In 2019, she has published a chapter of a book, participated in conferences, and published journal articles related to education and artificial intelligence (AI) that are indexed by ISI and Scopus. She is deeply involved in technology, this does not stop her from venturing into multidisciplinary areas, such as sustainability in education. She plans to expand her knowledge in many different areas so she can contribute more to society and the nation. Her area of expertise is multidisciplinary research. Her current research interests include integration and optimization of deep learning and regression. She has been a member of the Malaysia Board of Technologists (MBOT), since 2019.

HUI MIN LOW received the Bachelor of Science (B.Sc.) degree in speech sciences from the Universiti Kebangsaan Malaysia, and the Ph.D. degree in education from La Trobe University, Australia. She is currently a Senior Lecturer in special education programs. She is also with the School of Educational Studies, Universiti Sains Malaysia. She also has experience in the assessment and mediation of children with various types of speech and language disorders. Her main research interests include autism spectrum disorder, language teaching in special education, childhood multilingualism, speech and language pathology, augmentative and alternative communication (gestural communication), and childhood multilingualism.

AZAH ANIR NORMAN received the bachelor's degree from the Universiti Kebangsaan Malaysia (UKM), the master's degree in electronic commerce security from the Royal Holloway University of London, U.K., in 2004, and the Ph.D. degree from the University of Malaya (UM), in 2014.

She has experience with VeriSign Inc., Silicon Valley, CA, USA, in 2001. She was the Head of Customer Service with MSC Trustgate.com (a MDEC subsidiary and collaborator with VeriSign Inc., now part of DigiCert Inc.), where she specifically consulted many top 500 companies on Internet security implementation for their businesses, including oil and gas companies and financial institutions. She is currently a Senior Lecturer with the Department of Information Systems, Faculty of Computer Science and Information Technology, University of Malaya (UM), Malaysia. She is also passionate about issues regarding Islamic related ICT, such as Halal and Quran authentication, design thinking, and teaching and learning innovations. She is involved in various studies that have led to the publication of many academic articles in the areas of information security governance, information security management, information security systems, information security and trust, information security and privacy, information security education awareness, information security and assurance, and information security policy and governance. She is active with the working group WG/G/5-1 Information Security Management System, Standard Department SIRIM Malaysia, as an Expert in information security management systems and policy. Her works were published in respectable ISI-cited journals and a Scopus-cited journal. Her research interests include information systems, specifically information systems security, information security management systems (ISMS), ICT secure applications, human factors of security and privacy and information security governance, security in the social platform, and e-commerce security.

Dr. Norman is a member of the Association of Information Systems (AIS). She serves the Society for the Advancement of Knowledge and Excellence in the study and profession of information systems.