Analyzing the Effectiveness of Robotic Intervention among Autism Children in Learning Mathematics

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Abstract: In this study, it focuses on evaluating the effectiveness of the robotics intervention among the autism children in learning Mathematics. An investigation is conducted towards eight autism children in learning digit place values. This study reports on a preliminary work that examined on the use of Lego Mindstorm EV3 robot to increase the cognitive skills among Year 4 autism children. The study examined and compared the test results scores of the autism children in learning digit place value through robotics intervention as compared to traditional learning. The results revealed that robotic intervention style of learning had higher mean scores of the test results. In addition, the observations highlighted that students are more engaged, attentive and interested in learning using robots as assistive tools during lessons.

Keywords: Robotic intervention, autism children, traditional learning, cognitive skills.

Introduction

There are different levels of learning disabilities and are commonly identified as intellectual functioning or IQ, behavioral competence and the need for special service (Dandashi et al., 2015). Commonly, Autism Spectrum Disorder (ASD) is related to some levels of Intellectual Disability (ID), which consists of four levels and they are mild, moderate, severe and profound (Conti, Trubia, Buono, & Nuovo, 2018). Autism children tend to prefer robots more than humans as robots create a high level of motivation and engagement with people who are unlikely or unwilling to interact socially with human therapist. However, the effectiveness of robotics in learning for the ASD children is still at an infancy stage. Many researchers are skeptical on the benefits of robots and against the application of robots in real context such as for education and care of ASD children (Conti, Di Nuovo, Buono, & Di Nuovo, 2017). Hence, robotics intervention needs to be tested and assessed, to observe to what extent does robotic intervention assist ASD children in learning. Current research in the area of robotics intervention among the ASD children are dedicated to the design of robots with suitable physical features, control architectures, evaluation metrics and HRI algorithms that can be used in ASD diagnosis and therapy to improve the children's skills (Robins, Dautenhahn, & Dubowski, 2007). Huskens, Verschuur, Gillesen, Didden, & Barakova, (2013) mention that other research conduct study on robotics in autism therapy through improved research design, investigation of robots' features and abilities, and increasing robots' autonomy. Majority of these robotics research highlight the 'likability' of robots among the ASD children. Nevertheless, the demonstration of the robot's effectiveness in ASD therapy, education or diagnosis are scarce and limited

(E. Kim, Paul, Shic, & Scassellati, 2012). Therefore, the aim of this study is to investigate the effectiveness of robotics intervention in autism children's learning.

This paper is structured as follows. The next section is the literature review that presents previous works on robotics therapy for the autistic children. Next, the methodology that is adopted in this study is presented. This is followed by the results collected and discussion in section 4. Finally, a conclusion is made at the end of the paper.

Literature Review

The term "robotics" includes a variety of research subareas and each of them has different types of robots. There are three types of robotics, which carry distinct functions and they are Social Robotics, Assistive Robotics and Socially Assistive Robotics (SAR). D. Conti et. al., (2017), point out that Social Robotics are robots that take part in some types of social interaction with human, through speech, gestures and other ways of communication. As for Assistive Robotics, it helps to aid people with disabilities, especially people with physical and neurodevelopmental disabilities. Another type of robot is SAR, where it combines both functions of Social Robotics and Assistive Robotics. It is intended to assist via advanced interactions driven by user needs such as tutoring, physical therapy, daily life assistance and emotional expressions, through multimodal interfaces (speech, gestures and input devices). SAR often being related to play three main roles which are for companion, coach and play partner. In education and care for children, it highlights that SAR focuses its function as therapeutic application for children with developmental disabilities, such as those who are affected by Autism Spectrum Disorder (ASD) (D. Conti et al., 2017).

There have been numbers of existing studies that discuss on robotic intervention in education for the autism children. However, there are not many of them that particularly emphasize on the effectiveness of the robot itself, whether it is worth enough to be consumed or not by the targeted participants (Boucenna et al., 2014; Conti et al., 2017). It is essential to prove the level of efficacy of the robot as it helps to be an eye-opener for the parents, teachers and community towards the application of robots (D. Conti et al., 2017).

The scarce research that investigate on robotics interventions effectiveness for the autism children has shown effort in producing standard metrics for evaluating the impact of robotics to autism children (Begum et al., 2015). First, Begum et al. presented effectiveness metrics to evaluate robotics therapeutic effect to autism children. They highlight that majority of robotics research in this area uses common HRI metrics (Human-Robot Interaction) as a tool to measure robotics impact on autism children (Steinfeld et al., 2006).

Steinfeld et al., (2006) explain on HRI, where it is a metric that is used to measure and analyze how much effort human and robot must contribute independently and jointly to accomplish a task. The most common HRI metrics used are gaze (the duration or number of times the autism children looked at the robot) (Bekele et al., 2013; Scassellati, 2005; Tapus et al., 2012; Wainer et al.,2014), communication (number of verbal/non-verbal communication with the robot, total number of words exchanged with the robots and many more) (E. S. Kim et al., 2013; Scassellati, 2005; Wainer et al., 2014), affect (in an affective state or showing affective responses to the robots) (Feil-Seifer & Matarić, 2008; Kim et al., 2012; Robins et al., 2007), attention (their focus on the robots) (Robins et al., 2007), imitation (imitating the robots' action or speech) and proxemics (in a close proximity with the robots) (Feil-Seifer & Matarić, 2010). Even though the metrics perform well to demonstrate the general enthusiasm expressed by the autism children when they are around the robot, no studies provide a clear evidence of whether the autism children are actually able to learn the target skill taught by a robot and execute it independently, outside of the study setting.

Furthermore, Fitzgerald et al., (2015) highlight that paying attention is a major test for children with ASD, especially for them who have difficulties in making eye contact with others. They will not focus on things that do not interest them, which are things that involve shared attention. It needs a double effort to attract their attention. A child who faces severe attention problem is commonly diagnosed as Attention Deficit Hyperactivity Disorder (ADHD).

Attention is a cognitive process that encourages the attention focus from one place or event to another (Fitzgerald et al., 2015). It requires particular networks in brain like dorsal and ventral attention networks (DAN and VAN), to function well. It is learnt that paying attention is a key skill in learning.

As mentioned before, this study is interested to investigate the effectiveness of robotics intervention in autism children's learning. This include to understand whether they could comprehend what is learnt as taught by the robots that is related to the cognitive skills of the autism children. The next section explains the methods of study conducted.

Methodology

This study has conducted a preliminary work with the aim of introducing educational robotics among autism children and assess its usefulness as an assistive tool in learning. The main purpose of conducting this preliminary study is to determine the effects of robotic intervention on the autism children's learning.

A preliminary study is conducted at Sekolah Kebangsaan Sultan Yussuf, Batu Gajah, Perak, Malaysia. Eight autism children participated in this study. The aim of this study is to obtain the performance of the students when learning with robots vs traditional learning. The students were divided into 2 groups. Each group consists of 4 students with different gender, age and race.

Both groups consist of 2 girls and 2 boys with the between 10 to 13 years old. All of them are Year 4 students. They are placed in Year 4 based on their low IQ level. The picture of Group 1 and Group 2 are shown in Figure 1 and 2.

Figure 1. Group 1

Figure 2. Group 2

Students are provided with Mathematics module, which is on place value, base-ten. They are given two distinct modules: Module 1: 1&2-digit place value, and Module 2: 3-digit place value. Each student undergone different types of intervention (i.e. Traditional and Robotics Learning) to learn the modules. Referring to Table 1, Group 1 learnt the Module 1 through the traditional method and Module 2 through the robotics intervention. On the other hand, Group 2 learn the Module 1 through robotic intervention and the Module 2 through the traditional learning.

Table 1. Method of Testing for Group 1

Students	Modules	Method
A	Module 1: 1&2-Digit Place Value	Traditional
	Module 2: 3-Digit Place Value	Robot
B	Module 1: 1&2-Digit Place Value	Traditional
	Module 2: 3-Digit Place Value	Robot
C	Module 1: 1&2-Digit Place Value	Traditional
	Module 2: 3-Digit Place Value	Robot
D	Module 1: 1&2-Digit Place Value	Traditional
	Module 2: 3-Digit Place Value	Robot

Table 2. Method of Testing for Group 2

Students	Modules	Method
A	Module 1: 1&2-Digit Place Value	Robot
	Module 2: 3-Digit Place Value	Traditional
B	Module 1: 1&2-Digit Place Value	Robot
	Module 2: 3-Digit Place Value	Traditional
C	Module 1: 1&2-Digit Place Value	Robot
	Module 2: 3-Digit Place Value	Traditional
D	Module 1: 1&2-Digit Place Value	Robot
	Module 2: 3-Digit Place Value	Traditional

The robotics intervention uses a Lego Mindstorms EV3 platform. Using the Lego Mindstorms EV3 core set a robot known as the PvBOT was developed to teach digit place value Module 1 and 2. PvBOT is shown in Figure 3 and 4.

Figure 3. The PvBOT that teaches Module 1&2

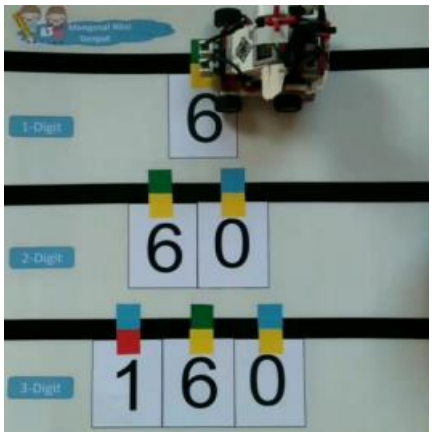

Figure 4. The learning activities using Lego Mindstorms EV3 to learn place values.

At the end of each learning module, students undergo a test to assess their learning (i.e. cognitive skills). They were asked to answer questions related to place values. The questions are the same for both learning interventions (i.e. traditional and robotics). The test questions are shown in Figure 5 and 6.

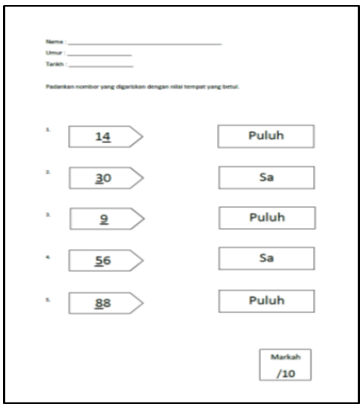

Figure 5. The PvBOT that teaches Module 1&2

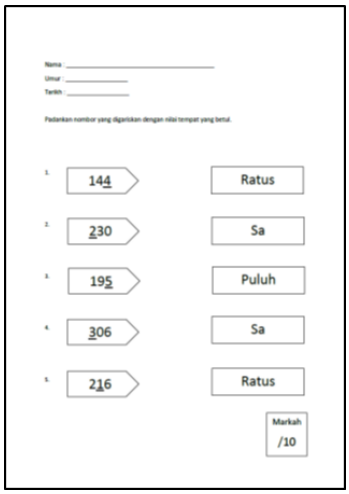

Figure 6. The PvBOT that teaches Module 2

Observations is also conducted throughout the learning sessions by the researchers. Observations were done in unobstructed manner. All observations were jotted down in the researcher's journal and notebook in classrooms.

Results & Discussions

In this section, two types of data analyses results are presented. First, students' test scores for Module 1 and 2 are presented in Table 3 and 4, and discussed further in the paragraphs that follows. Secondly, at the end of this section, the observations are presented and summarized.

Referring to Table 3, data shows that Group 2 performs better than Group 1 in learning the 1&2-Digit Place Value module. This is based on the students' mean score as shown in Table 3. The mean score is 88.75 for robot-based teaching method (Group 2) as compared to only 60.00 mean score for traditional method (Group 1). To recall, Group 2 learnt through robotics intervention while Group 1 undergone the traditional learning for this module. It is concluded that learning through the robotics intervention method for the 1&2 Digit Place Value module assists Group 2 students to be able to be better at paying attention and remember what was taught to them (i.e. cognitive skill).

Table 3. Students' Scores on Module 1 (1&2-Digit Place Value)

Module 1 (1&2-Digit Place Value)			
Traditional Method		Robot Method	
Group 1 Students	Results	Group 2 Students	Results
A	55%	A	85%
B	45%	B	75%
C	65%	C	95%
D	75%	D	100%
Mean	**60%**	**Mean**	**88.75%**

Table 4. Students' Scores on Module 2 (3-Digit Place Value)

Module 2 (3-Digit Place Value)			
Traditional Method		Robot Method	
Group 2 Students	Results	Group 1 Students	Results
A	65%	A	80%
B	45%	B	100%
C	65%	C	95%
D	75%	D	100%
Mean	**62.50%**	**Mean**	**93.75%**

On the other hand, Table 4 presents the results for both groups in learning the Module 2 on 3-Digit Place Value. The collected test results in Table 4 has shown that Group 1 has a higher mean score in terms of performance that is 93.75 as compared to Group 2 that has a mean score of only 62.50. To recall, in learning Module 2, Group 1 was given the opportunity to learn through the robotic intervention method while Group 2 undergone the traditional learning. It is concluded that robotics intervention in learning is impactful to improve students' cognitive skills in learning Mathematics in the context of our study.

Based on the results of the mean scores shown in Table 3 and 4, this study has a reason to believe that robotic intervention is effective for students in learning. It is believed that robots could play an important role as an assistive tool in teaching and learning practices for the autism children.

Secondly, the observation conducted in this study has shown that robotics teaching brings many positive values to the classroom settings. This can be seen from the evidence shown in the picture taken during the lesson (refer to Figure 7 and 8). It is seen that students were more active and are able to play during robotics class as compared to the traditional learning settings (see Figure 8). Other observations noted throughout the lessons were summarized in Table 5.

Figure 7. Students behavior during traditional learning

Figure 8. Students behavior during robotic learning

Table 5 Comparison between Traditional & Robot Method

Traditional Method	Robot Method
i. They sit far away from each other.	i. Students come closer during learning.
ii. They did not focus during learning.	ii. Students observe the reactions of other students and their instructor.
iii. Facial expression shows no interest and boring.	iii. Expression on their face was extremely happy and shows interest toward the robot.
iv. Poor interaction between students and instructor	iv. Better for interaction between students and instructor.
v. Student has poor interaction between classmates	v. Interaction with classmates is easier as they communicate during learning.

During the observation, it was noted that the robotics group of students showed interest when interacting with the robot. The students were very satisfied with the robot usage and actively engaged in learning place value as they were getting encouragement from the robot. For instance, after the robot taught about place value, students were asked whether they understand the lesson. Without further prompting, all of the students in the group responded "yes" instantly. Furthermore, when asking the student to answer the place value of the numbers, the introvert students responded immediately. Hence, this study has found that introvert students are eager to join the learning activities.

Moreover, our observation noticed that majority of the students in the robotics group managed to focus, concentrate and be attentive while engaging with the robot as compared to the traditional classroom settings. The students were excited to understand what the robot could teach them. In addition, while the robot performed teaching, the students were all quiet and concentrating. Thus, the behavior observed has highlighted that students were immersed and engaged in learning place value.

Conclusion

This study concludes that robotics is an effective assistive technology that could teach as well as enhance cognitive skills among children with learning disabilities. In this study, it has been observed that the Lego Mindstorms EV3 (i.e. PvBOT) creates an exciting learning environment and could increase students' engagement level. Moreover, robotic intervention creates both enjoyable and challenging learning settings. This could assist the difficulties and tough responsibilities of teachers in teaching the autism children with learning disabilities. Finally, this study has a reason to believe that robotic intervention is an effective assistive learning tool for autism children in such that it enhances engagement, attention and interest in learning. Nevertheless, more real case studies are welcome to investigate the effectiveness of robotics in learning other subjects that include language, science and many more.

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