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A CONCEPTUAL FRAMEWORK FOR AUTOMATED ASSISTIVE LEARNING USING ROBOT FOR AUTISM: A REVIEW

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ABSTRACT

As rapid advancements continuously alter the way we do things and enhance our daily activities, these technologies are merely tailored for normal citizens causing people with special needs, including people with autism, to be left behind. In this 4IR era, technology such as robot technology is advancing very fast and this offers a very big opportunity for inclusion of students with special needs especially ASD since research has shown that ASD children gained advantages in many aspects by using robots in their learning process. This paper aims to present a list of existing robots that can be used to support ASD education, existing robot interactive recognition features that can be used to support ASD education, and elements of a framework for enhancing existing robot technology and recognition features to provide effective automated assistive learning technology for ASD education. A review of existing robots and robot recognition features that can be used to support ASD education were conducted. The review continued to reveal the elements of a framework for enhancing existing robot technology with recognition features to provide effective automated assistive learning technology for ASD education. The results are a report on four generations of robots and six humanoid robots that can be used for autism assistive learning. The outcome also includes eye tracking, face recognition and emotion recognition which are three important recognition methods embedded in the robots to make it interactive to humans and therefore suitable to be used to support ASD assistive learning. Last but not least are two conceptual frameworks proposed for enhancing learning effectiveness by using robots. The conceptual framework aims to provide automated assistive learning technology by enhancing existing robot technology and integrating new recognition features for ASD learning purposes.

Keywords: *Humanoid Robot, 4IR, Autism, Assistive Learning, Recognition*

1. INTRODUCTION

As a human being education is important in our life [1]. Education is also important to everyone from early education to higher education. But in certain places around the world, the type of all education is still a long way or remains unchanged as compared to the type of education in other places. In the global and local landscapes, a pressing issue has been illustrated, in which the underprivileged community, especially children with special needs [2], are left behind. As we move towards a quality education, there is an urgent need for learning to be inclusive regardless of special needs, especially children with ASD [3]. ASDs are a special group of people or children known as Autism Spectrum Disorder (ASD). ASD is a behavior that can be defined as a neurodevelopmental disorder. To date, an increasing number of children across the globe are being diagnosed with autism ASD causes a child to experience persistent problems in social communication and interactions across multiple contexts as well as show restricted, repetitive patterns of behavior, interests, and activities [4]. These symptoms can be categorized as mild but severe symptoms require more support in daily life [5]. The communication disorders in ASD involve impairment in the use of facial expression and others like lack to start a conversation and abnormality in understanding of emotion [6]. As a society in the community, assistive learning needs to be realized that children and disorder children need a special education either content such as framework or platform.

The conventional learning method for ASD children at first requires direct learning from parents [7]. ASD children need special care from their parents because ASD children find it difficult to be understood. The next level of direct learning is from a teacher or instructor [8] which teaches the ASD children to communicate socially between ASD children. Later learning aids were introduced to support learning for ASD children and also help adults for better understanding of ASD children need, to make the support learning more effective and interesting. In previous research with regards to support learning, children with autism usually learn about social communication and interactions with physical media such as visual cards [9]. For example, in indicating whether a child is in hunger, visual cards help to indicate level of hunger. Other support learning for example in study [10] implement class base activity for ASD children which later divide from whole group instructions until individual instructions with the monitor from teacher. While in study [11] assistive learning using media [11], tablet [12], 3D courseware [13], and 2D interactive CD [14] were shaping. Those studies were implemented to where this kind of media used for training or therapy via verbal expression, 3D animation & singing or interactive learning given through drill and practice. The purpose was to shape an understanding in the brain of the student and make it formed through repetition. With the current technology, the conventional learning method becomes less effective and less engaging to support learning for ASD.

As we live in the era of Fourth Industrial Revolution (4IR), the way of learning has changed, the new concept of learning has been introduced in order to make the assistive learning more effective and interesting. This new concept of learning also can be applied to special education for ASD children. This modern learning implements the 4IR technology that is possible to make the assistive learning more effective and engaging. For example, Santos et. al. [15] supported a universal learning approach to promote mathematical reasoning for the ASD children by creating creative and constructive environments and the development of differentiated, meaningful and quality activities to support learning for ASD children. While Idris [16] implemented a game-based learning to support learning of ASD children to stimulate the motivation in learning. Also, Liao [17] and Bahrami et. al. [18] claimed that game-based learning is more effective than the conventional way of learning.

Another assistive learning method that has been implemented with robot toys and later become learning aids in order to support learning using robots that interact with ASD children. One example is a study [19] that uses robot toys to socially interact with the ASD children. However, using robot toys only could not be very effective to support learning for ASD children because of the limited learning modules. In order to make the assistive learning more effective for ASD children, further research is required to equip robots with more learning modules and new robot technologies.

Existing robots are now provided with new functions such as image or sound detection, and face and emotion recognition that make it more interactive and intelligent for assistive learning. Leo et. al. [20] reported that robots can recognize emotion of ASD children and enhance better treatment for them to interact. Related study done by Costa [21] uses a robot developed by robots4autism to help ASD children to identify emotion for engaging communication. This robot teaches the ASD children by using robot voice to communicate and show the expression so that ASD children are more comfortable with the robot.

Previous research has shown the effectiveness of robots as assistive learning technology to support children with autism. Cognitive and sensory deficits of ASD children can be reduced by using robots in the learning process. [22][23] ASD children prefer contact with robots than human instructors [24]. Advantages gained by using robots in the learning process include improving social skills,

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communication, emotion control, and developing metacognitive skills. [23] Having positive signs of using robots in the learning process and with the rapid advancement of 4IR especially robot technology, give us strength to further research to innovate and contribute to autism inclusion.

This paper aims to present a list of existing robots that can be used to support ASD education, existing robot interactive recognition features that can be used to support ASD education, and elements of a framework for enhancing existing robot technology and recognition features to provide effective automated assistive learning technology for ASD education.

2. REVIEW APPROACH

To limit the papers to be reviewed, the search and selection strategy were implemented using specific keywords in electronic databases containing relevant study, journal, conference proceeding and website. The results started with 162 articles and narrowed down to 76.

As a guide to the review process, we have constructed the following research questions:

RQ1: What kind of existing robots that can be used to support ASD education?

RQ2: What are the robot recognition features that can be used to support ASD education?

RQ3: What are the elements of a framework for enhancing existing robot technology and recognition features to provide effective automated assistive learning technology for ASD education?

Search strategy

At first conducting searching for the studies that relate to this study which is ASD in support learning using robots and the interactive recognition method. The search strategy applies using an electronic database that contains relevant study, journal, conference proceeding and website. For this study, the electronic database was a main source to get a related and relevant study. Electronic databases like ResearchGate provide 130+ million publications. Other, available electronic databases like Science Direct provide 12 million pieces of content like journals. E-book also a part of electronic databases like google books, provide free and paid access to the e-book in the Google Books and Google Scholar. After performing the literature search using electronic databases, other search strategies such as internet source apply in this study can also be a primary and secondary literature and can be seen in (table 1).

Table 1: Summary of Search Protocol

Database	Search Protocol
ResearchGate	Search String: Robot + ASD + Education + Recognition
Science Direct	Search String: Robot + ASD + Education + Recognition
Google Book	Search String: Robot
Google Scholar	Search String: Robot
Internet Source	Related sources

Selection strategy

This review focuses on articles that reported the use of robots in ASD education. Selected studies were relevant to ASD education context and focused on robot or robotic influence on learning, pedagogical and development domains. The studies selected should report the use of robots as a learning aid.

Given the broad inclusion criteria, 162 articles were managed to be found in all (see figure 1). To further narrow down the scope of the review, the following exclusion already be implemented:

- Exclusion Criteria E1: Article did not mention the use of robots in any education.
- Exclusion Criteria E2: Article did not mention ASD.
- Exclusion Criteria E3: Article did mention about robots only.
- Exclusion Criteria E4: Article did not mention learning using robots for ASD education.
- Exclusion Criteria E5: Article showed no direct connection to the study.

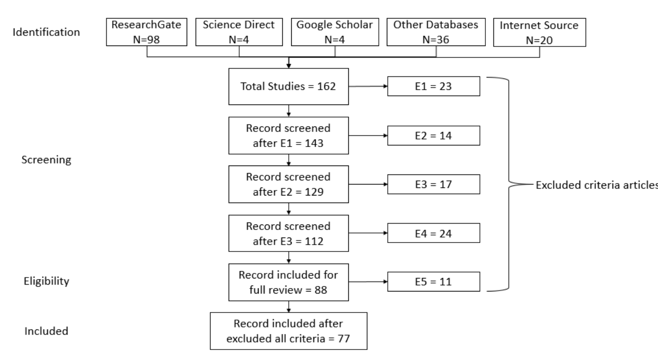

Figure. 1: Summary of Selection

Figure 1 shows the study inclusion and exclusion flowchart based on Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) checklist for this paper review. The PRISMA checklist is an extensively used protocol for systematic reviews and meta-analysis across disciplines to ensure high-quality review [25].

3. ROBOT TECHNOLOGY

This section discusses the answer to RQ1. Results of the paper review on the existing robot technology can be described in four generations of robot evolution [26]. The first generation was started with industrial robots which occurred between 1950 until 1967. In this generation, the robots were programmable machines designed to increase productivity with rapid technological development and to improve industrial production, or to be automated machines. Programmable robots in generation 1 are robots that are programmed to do specific tasks such as pick and drop or loading & unloading. These robots can be programmed or controlled by "logic gates" as automatic regulators [26]. Later, the numerical control (NC) was introduced by machining-tools manufacturers to enable other manufacturers to produce better products [27]. The combination between the manipulators and the NC capable machining tools paved the way to the first generation of robots. Robotics originated as a solution to improve output and satisfy the high quotas of the U.S. automotive industry. In parallel, the technological growth has resulted with the creation of the first digitally controlled mechanical arms which enhanced the performance of repeatable," simple" tasks such as pick and place. The first known robot is UNIMATE, a programmable machine invented by George Devol and Joe Engleberger [28]. UNIMATE helped boost production, which motivated other companies and research centers to invest more resources in robotics.

Starting from 1968 until 1977, the second generation of industrial robots occurred. The robots were programmable machines too but with limited sensor's integrated. Instead of logic gates, programmable robots in generation 2 are controlled by microprocessors (Programmable Logic Controllers - PLC) and can be programmed by an operator using a teach box [26]. These robots are capable of responding to the environment and provide responses that meet various challenges. These robots can do more complex tasks compared to generation 1 robots [26]. However, mainly the robots are in the form of robot arms, not humanoid. Shakey [29], developed by Stanford Research Institute, was the first sensor mobile robot, equipped with a range of sensors such as tactile sensors and a vision camera. In the industrial environment, the PLC [30], industrial digital computers have been designed and adapted to control manufacturing processes, such as assembly lines, robotic devices or any activity that requires high reliability. PLCs were considered easy to program. Because of these characteristics, PLCs have become a commonly used device in the automation industry. The T3 robot was the first commercially robot controlled by a microcomputer.

In the third generation of industrial robots from 1978 until 1999, many consider that the Era of Robots started [31] in this generation. Third generation robots can interact with the operator and the environment and have self-programming ability. The robots are programmable either online by operators or off-line via a PLC or a PC. High level languages can be used to program these robots. In addition, interface to CAD or databases also could be done. Compared to the previous generation, these robots also provided advanced sensors, embedded with AI techniques, and could be used in more complex tasks [26]. Robots have grown in the industrial sectors to automate a wide range of activities such as painting, soldering, moving or assembly. From sensored mobile robots in the second generation, then through this third generation the robot in this time "robot programming languages" became popular and applied in robots and moved autonomously. For example, UNIMATE started using VAL in 1979 [32] making robots reprogrammable machines that also included a dedicated controller. By the end of the 1990s, companies began to think about robots outside the industrial environments.

The fourth generation of robots occurred from 2000 until present. Some of these robots have high-level intelligent capabilities such as advanced computation, deep learning, and collaboration. These robots also contain more sophisticated sensors that helped them to adapt more effectively to different circumstances. In this generation, the robot can be classified into two types: non-humanoid and humanoid robots.

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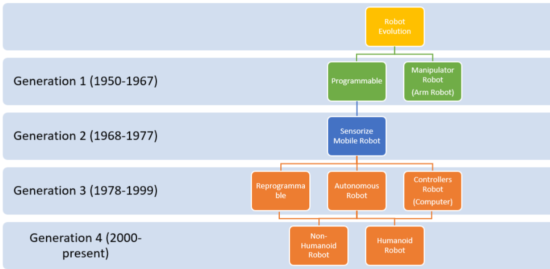

Figure 2: Robot Generation

A non-humanoid robot is a robot that has different body shapes and can be any creature as long as the robot does not aim to imitate humans in form and vaguely in function [33]. This type of robot has many designs of body shapes and serves different purposes. For example, non-humanoid robots are LEGO Mindstorms kit [34] and robot dog Aibo that has body shape resembling a dog body. This type of non-humanoid robot can fall in many categories such as aerospace and drone robot, consumer robot, disaster response robot, education robot, entertainment robot, industrial robot, research robot, telepresence robot, underwater robot and military & security robot.

A humanoid robot is a robot that has a body shape built to reflect or resemble to the human body [35]. This type of robot was designed to look like people and the movement was the same as people. Also, this robot may be for functional purposes only like interacting with humans. Examples of humanoid robots include Honda's ASIMO, which has a mechanical appearance, and androids like the Geminoid series.

Humanoid robot also can be classified to non-programmable and programmable: -

Non-programmable robots are robots that are already programmed for specific task examples like pick and drop. Usually these types of robots are already programmed during production, engineer [36] and cannot be re-programmed. Examples are the Ubtect robot like lynx, alpha 1, alpha 2 and AI-powered robot assistants.

A programmable or fully programmable robot can be re-programmed according to the functional purpose like a multifunctional manipulator [37]. This type of robot can be reprogrammed many times for other tasks. Examples of this robot include Nao, Darwin, UXA, Qt, Misty, and EMYS.

The industrial robot is greatly well performed for the manufacturing process which normally consists of a manipulator arm designed to perform repetitive tasks [38]. Meanwhile in education, the robot can be used to facilitate teaching and to support the learning process. For example, study in [21] use a robot developed by robots4autism to help ASD children to identify emotion. This robot teaches the ASD children's by using robot voice to communicate and show the expression so that ASD children's more comfortable with the robot. With the help of robots, ASD children can make their robot as a friend then later tend to speak with the robot more often which is good for their communication skills.

Nao robot is an autonomous, programmable humanoid robot developed by Aldebaran Robotics Company [39]. Nao robot itself is already popular among researchers in ASD study previously [40] because of the ability to program the robot and the ability to implement it with AI. Those features are needed by the research and the performance of Nao are great compared to the other robot. The AI feature in the Nao robot can be used to implement the AI technique and learning module for ASD children. According to the review by [41], the Nao robot can be very fragile and needs to be programmed for movement very carefully because it can easily fall and break. Also, the Nao robot has bad speech recognition and does not work in noisy environments. Another weakness of this robot is the Nao robot is overrated [42] because with the price and ability of the Nao it can get a lower cost and has the same ability as the Nao robot.

Darwin-OP was introduced in 2011 by the Korean Company Robotic [43]. This robot may be underrated among researchers because this robot is the newcomer compared to the Nao robot that already established the Nao name. But this Darwin-OP has the same ability as Nao except the size of Darwin-OP is smaller than Nao. This robot is used mainly for research and education purposes [44]. It is an open platform humanoid robot which has an expandable system structure, high performance, simple maintenance, familiar development environment and affordable prices [45] which is the biggest advantage of this robot compared to the Nao robot. The weakness of this robot during the execution task can take a while to perform the task [46].

UXA-90 is a humanoid robot that is mainly used for multipurpose research. This robot is a well-proportioned 1m tall humanoid shaped robot. It was designed with a structure to the ratio of the ideal human body. The skeletal structure of this robot imitates the one for a human, it is possible to produce humanlike movement patterns. This robot has the ability to recognize and track the color and shape of an object with the camera in this robot. Also, this robot is capable of doing HRI (Human Robot Interaction) which is the robot and human can interact with each other. This ability can be a big advantage for ASD children to interact with the robot.

Qt robot is a programmable humanoid robot developed by LuxAi Company. Qt robot already established the name in the autism robot field and has won several awards like at Consumer Electronics Show CES trade show 2019 [47]. This robot expresses humanoid social robots that express the emotion as human [48]. This robot developed to help autism in terms of learning and many users already use this robot in autism learning and they give good feedback about this robot. This robot is capable of being reprogrammed to the developer tools that enable the robot to be programmed. This robot also has a good camera quality [49] and the AI capability to do facial recognition, those features can be advantageous.

Misty II is a programmable robot developed by Mistyrobotics Company. Misty II robot can be referred as a newcomer in the robotic field when the first lunch in CES 2018 with the first Misty robot [50]. The Misty II robots are the upgraded version of misty robots with the feature like better camera. Misty II robots mainly use as a multipurpose robot-like education and as socially assistive therapy. This robot has an ability as an open platform which can be integrated with third party support and fully programmable robots. Capable of implementing AI technique with the camera ability that can-do facial recognition. With technologies like AI [51] this is a big advantage for a robot with an AI program and this robot has a good camera.

Ubtect Lynx robot is more likely a smart home robot that mainly used as an entertainment and surveillance robot. This robot has the ability to detect the facial of a stranger and be controlled by using a smartphone. However, this robot is not suitable due to lack of features to program the robot. This is a main disadvantage for this paper review that needs the robot to be programmed to recognize the face and emotion of ASD children. Another weakness of this robot, the images taken by this robot are blurry [52] which is not suitable.

For this paper review, the robot required must be fully programmable and has a good camera and image quality for the face and emotion recognition. An AI engine also needed to develop a face and emotion recognition model.

4. INTERACTIVE RECOGNITION METHODS

This section briefly presents existing works related to ASD assistive learning using robot and prediction techniques used for ASD. One of the techniques is deep learning neural network and convolutional neural network. So far, deep learning has shown great success in various machine learning tasks, such as object recognition and sentiment analysis [53]. Recognition methods are the methods that are used to recognize something like a ball for example. While the interactive recognition method is the way of recognition methods that become interactive within the system and humans for example robots recognize human faces. Recognition method can be anything which is: -

A. Eye tracking

Eye tracking is a process of tracking eye movement to determine where the user is looking at [54] for example screen monitor. This method uses the camera to track the eye movement of people according to what the people see. This method is capable of tracking every eye movement from one point to another point. The reason eye tracking was proposed was to track the eye of ASD children to ensure the ASD children's focus on the support learning. For example, in study [55] they implement eye tracking to see the ASD kids are giving attention to visual support learning. Therefore, if the eye of ASD children is not on the robot then the robot gives the notification to the therapist. Also, this feature can be a good way to observe the focuses of ASD kids. As we know ASD kids tend to lose focus and

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get bored easily compared to the normal kids. For this method will be implemented to see the focus of the ASD kids during support learning. While other studies also implement the eye tracking method in their study by using Tobii Studio Analysis Software [56] to study people focused on the monitor. This eye tracking method will be implemented with machine learning based classification [57] that classifies the eye movement of the ASD children. This feature also can track the eye in real time.

B. Face recognition

Face recognition is a method that recognizes a human face. This method does detection on the facial feature like eyes, nose, mouth [58] and human face and selects the facial feature. After selecting the human face and other features later will be trained with AI models like Convolutional Neural Network (CNN) technique. The reason the model needs to be trained is because face recognition is a challenging task since human faces may appear in different scales, orientations and with different head poses [59], so this process to get a better accuracy. When the model is done later the model will be implemented with the robot to identify and differentiate the ASD children's and normal children. This face recognition recognizes the face in real time which is on the sport this model can identify the face of ASD children and normal children. Other than CNN techniques, deep learning neural networks also can be applied to this paper review for example in study [53] use deep learning neural network to implement in the support learning and robot from face images of ASD kids. From those studies the method can be implemented and be improved in this paper review.

C. Emotion recognition

For emotion recognition is the same method as face recognition but the difference is the emotion recognition uses the emotion on the human face to determine the emotion of the people. This emotion recognition will also be implemented with the CNN approach [60], which the model will be trained with the emotion face of ASD children. This method also will be implemented with the robot use to identify and determine the current emotion of ASD children's also to predict the facial expression label which should be one these labels: anger, happiness, fear, sadness, disgust and neutral [61] of the ASD children. From the emotion recognition, the current of emotion of ASD children can be determined by the suitable support learning module and from the current emotion recognition also can determine the time of support learning for the ASD children. This feature also can be used in real time facial emotion recognition [62] to recognize the face emotion of ASD which is good for ASD children that are always changing the emotion frequently. Also, other than CNN technique, deep learning techniques from previous study in [63] they apply the deep learning neural network to identify the emotion from the facial expression recognition of the ASD kids. But in their study, they set different parameters of models in each experiment and the corresponding result is then compared to get the best result. Those studies show that this method can be used to recognize the facial expression of ASD kids.

5. AUTOMATED ASSISTIVE LEARNING MODULE USING ROBOT

As we are in the 4IR era, many applications have been integrated with 4IR technology and there is no exception in the education aspect. There are many learning aids that have been integrated with 4IR technology, and one of them is using robots during learning activities. Robots can be used for non-assistive learning but also can be implemented for ASD assistive learning. In this section, we proposed two conceptual frameworks to increase learning effectiveness by using robots in the learning activities for non-assistive learning and ASD automated assistive learning engagement.

1. *Non-Assistive learning engagement*

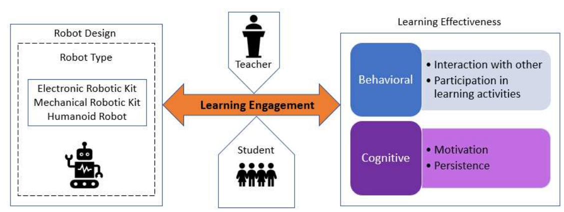

Figure 3: A Conceptual Framework for Effective Learning using Robot for Non-Assistive Learning Engagement

The proposed conceptual framework shown in figure 3 explains the primary components for effective learning using robots in a non-assistive learning engagement. Non-assistive learning means the learning situation involving normal children. For a non-assistive learning engagement, the learning efficacy can be achieved by using any robot type such as electronic robotic kit, mechanical robot kit or humanoid robot.

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The proposed conceptual framework is adapted from studies by [64],[65]. This conceptual framework allows the robot design to serve the purpose. From the robot design and the robot type, the learning engagement from students can be measured from 2 aspects which are behavioral and cognitive [66].

Behavioral engagement is the degree to which students participate actively in learning activities. Criterion of behavioral engagement consists of time and effort spent participating in learning activities and interaction with peers and robots. Behavioral engagement can be measured by reflecting observable student actions and original conceptualizations of student engagement towards learning. Using robots in the learning process will improve the students' behavior in terms of interaction with others [67]. Also, with the robot, students seem to actively participate in learning activities more often as compared to with the instructor [68].

While cognitive engagement is the degree to which students invest in learning and expend mental effort to comprehend and master the content during the learning process. Criterion of cognitive engagement consists of motivation to learn. While cognitive engagement includes motivational aspects, the student showed constant motivation to interact with the robot [66],[69] The robot encourages a sense of motivation and promotes interest in students to engage more in learning. Persistence is also important in learning which for example to overcome academic challenges and meet/exceed requirements. Also, the ability to focus and concentrate on one attention [70].

2. *ASD automated assistive learning engagement*

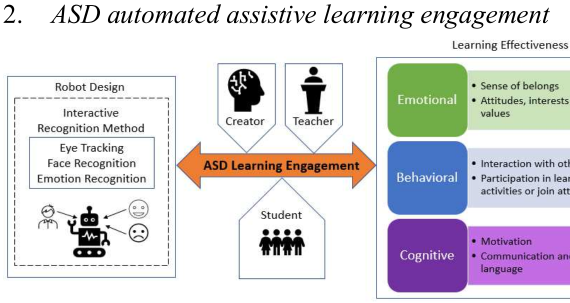

Figure 4: A Conceptual Framework for Effective Learning using Robot for Automated Assistive Autism Learning Engagement

Accordingly, the proposed conceptual framework shown in figure 4 explains the primary components of an efficient learning engagement for both side which is student and teacher as the users of interactive robot learning aids. As for creators or instructional designers who develop the interactive robot, automated learning modules need to know what students and teachers need for assistive learning activities. The efficacy of learning engagement with robot learning modules also consists of the interactive recognition method which is eye tracking, face recognition and emotion recognition.

This conceptual framework allows the robot design to identify the typical children and ASD children during a learning process with the interactive recognition method. From the robot design and interactive recognition method, the learning engagement from a typical student or ASD student can be measured from 3 aspects which are emotional, behavioral and cognitive [71].

Emotional engagement is a typical student or ASD student's affective reactions during a learning process. Criteria of emotional engagement consist of imitation of emotion and understanding their emotion expression in the correct way within a learning time. Emotional engagement often provides insight into how typical students or ASD students feel about a particular learning, delivery method, or instructor. By using robots, ASD children can imitate the emotion of robots so that the ASD children understand their emotion base on imitating the emotion shown on the robot [72] and express their current emotion so that people understand their situation [73]. Also, from the robot design, ASD children can identify the situation based on emotion [74].

Behavioral engagement is the degree to which students participate actively in learning activities. Criterion of behavioral engagement consists of time and effort spent participating in learning activities and interaction with peers and robots. Behavioral engagement can be measured by reflecting observable student or ASD children actions and original conceptualizations of student engagement towards learning. Using robots to support learning may improve the behavior in terms of interaction with others and speak more to their playmates [72],[74]. Also, with the robots around, ASD children showed active participation in learning activities or joint attention more often as compared to the instructor [75],[76].

Finally, cognitive engagement is the degree to which students invest in learning and expend mental effort to comprehend the content. Criterion of cognitive engagement consists of motivation to learn. While cognitive engagement includes motivational aspects, the ASD children showed constant motivation to interact with the robot [74],[77]. The robot encourages a sense of motivation in ASD children to engage more in assistive learning. By interacting with the robot, ASD children would enhance their communication skills in daily life [75] and improve the spontaneous language ability during assistive learning better than instructor [72].

As a conclusion, the impact of learning using robots for non-assistive learning and assistive autism learning in learning activities is slightly different in terms of learning engagement in which the duration of learning time for autism children cannot be the same as non-assistive learning because autism children more likely to lost focus during learning process as compared to the typical children [78],[79],[80]. But with the robots, the learning duration can be shortened and can be changed to other interactive learning to engage more autism children during the learning time. Also, in terms of emotion, usually emotion of a typical is not easily disrupted as compared to the ASD children. With the robots, ASD children can control their emotions better as compared to not using robots.

6. DISCUSSION

In this 4IR era, technology such as robot technology is advancing very fast and this offers a very big opportunity for inclusion of students with special needs especially ASD since research has shown that ASD children gained advantages in many aspects by using robots in their learning process. As reported in section 3, we can see that the robot technology is now in the fourth generation which is programmable, sensorize, autonomous either humanoid or non-humanoid. This generation of robots are more intelligent and inclusive with advanced computers and sophisticated sensors that allow them to be reprogrammable and become autonomous [81],[82]. Section 3 provides answers to RQ1 of this paper while section 4 discusses answers to RQ2 of this paper. Eye tracking, face recognition and emotion recognition are three important recognition methods embedded in the robots to make it interactive to humans and therefore suitable to be used to support ASD assistive learning. In section 5, we present answers to RQ3 by discussing elements of two proposed frameworks for enhancing existing robot technology and recognition features to provide effective non-assistive learning engagement for typical students and automated assistive learning engagement for ASD education.

7. CONCLUSION

Since research has demonstrated that robot technology offers an added advantage to ASD children, the main goal of this paper is to review how ASD children can engage more in their learning by using robots and the robot recognition features. As a conclusion, two conceptual frameworks are proposed for enhancing learning effectiveness by using robots. For typical students, learning engagement can be achieved by using robots of either electronic, mechanical or humanoid types and the learning effectiveness can be improved and measured by assessing them on the behavioral and cognitive dimensions. On the other hand, for ASD children, learning engagement can be achieved by using robots with interactive recognition methods and the learning effectiveness can be improved and measured by assessing them on behavioral, cognitive and emotional dimensions.

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Table 3: Robot Review

	Specification	Strength	Weakness
Nao V6 (2018)	**CPU** ●Intel Atom E3845 Quad Core @ 1.91 GHz, 4 GB DDR3 RAM, 32 GB SSD **Camera** ●Two HD OV5640 **Sensors** ●Sonar, infrared, pressure, and tactile sensor **Dimensions** ●58cm height **Connectivity** ●Ethernet, Wi-Fi, Bluetooth	●Fully programmable for programming language which Drag Drop, C++, Python, Java ●Equip with 2 cameras ●Easily to program the robot ●Has good anti-collision system	●Can be fragile ●Overrated ●Terrible speech recognition and do not work in a noisy environment ●Cannot walk fast because can be fall easily
Darwin-OP 3 (2018)	**CPU** ●Intel core I3 Dual Core @2.1 GHz dual core, 8GB DDR4 RAM, 128GB M.2 SSD **Camera** ●Logitech C920 HD Pro Webcam **Sensors** ●Ultrasounds, Proximity and Motion sensors **Dimensions** ●51cm height **Connectivity** ●Ethernet, Wi-Fi, Bluetooth	●Fully programmable for programming language which (C ++, Python, LabVIEW, MATLAB) ●Open source ●Can change and redesign the robot hardware	●Battery can wear out ●Takes a while to perform task
UXA-90 (2014)	**CPU** ●CPU: AMD E2-1800 Processor dual-core 1.7GHz, 2GB DDR RAM, 64GB (SSD) **Sensors** ●Inertial: IMU 2g 9axis ●FSR module (optional) x2: 4 sensors in each foot **Camera** ●Logitech C905/ HD 1600x1200 PX **Dimension** ●100cm height **Connectivity** ●Wi-Fi	●Fully programmable for programming language using Visual C#	
Qt Robot (2017)	**CPU** ●8th Gen quad-core Intel® Core™ i5/i7, 16 GB DDR4 RAM, 256 GB M.2 **PROCESSOR 3D CAMERA** ●Intel® RealSense™ Depth Camera D435 **SENSORS** ●Feedback from position, speed, temperature, load, and voltage **DIMENSION** ●65cm height **CONNECTIVITY**	●Fully programmable for programming language which Python and C++ ●3D camera for facial recognition ●Has LCD screen that can show an emotion ●Long battery life	●Static can only move head and hand

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	●Ethernet, Wi-Fi		
Misty II Robot (2018)	**CPU** ●Qualcomm® SDA 820™ processor and Qualcomm® SDA 410™ processor, 4GB RAM, 16GB **COMPUTER VISION/ CAMERA** ●Occipital Structure Core depth sensors for 3D maps ●4K camera ●Deep-learning AI using Qualcomm® Snapdragon™ Neural Processing Engine **Sensors** ●Capacitive touch sensors, distance and obstacle detection, IR-based time-of-flight sensors, bump sensors **Dimension** ●36cm height **Connectivity** ●Wi-Fi, Bluetooth	●Fully programmable for programming language which Python, C++, JavaScript Accessories can be customized ●Has LCD screen that can show an emotion ●Multipurpose robot ●Good camera for facial recognition ●Has obstacle detection	●Noticeable audible fan
Ubtect Lynx (2017)	**CPU** ●RK3288 Max 1.8GHz 4*Cortex-A17, 2GB RAM, 16GB **Camera** ●HD camera with facial detection **SENSORS** ●Gravity Sensor, Gyroscope Sensor, Capacitive touch sensors and PIR Sensor **DIMENSION** ●44cm height **CONNECTIVITY** ●Wi-Fi	●Can work as a yoga instructor ●Can be controlled by a smartphone ●Can be used as a surveillance robot for home	●Walks very slow ●Blurry photos ●Not a programmable robot