2024 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM)

Development of an Interactive Learning Assistive System for Students with Intellectual Disabilities Using Robot with Audiovisual Intervention

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2024 International Conference on Computer Engineering, Network, and Intelligent Multimedia (CENIM) | 979-8-3503-6880-2/24/$31.00 ©2024 IEEE | DOI: 10.1109/CENIM64038.2024.10882671

Abstract—**Intellectual disability is a condition in which an individual has a below-average intellectual level, resulting in difficulties in the learning process. To fulfill the right to education, the government has developed a policy through the implementation of special school. However, despite the existence of SLB, the learning process of students with intellectual disabilities often does not run smoothly because they have difficulty focusing on long-term instructions and are easily distracted by visual distractions. Therefore, assistive technology is needed that is able to attract students' attention during the learning process. Previous research has developed a robot-based interactive learning system for people with intellectual disabilities that is able to improve students' understanding of the material. However, the robot system does not yet have a two-way interaction feature between the robot and students. This research aims to develop the interactive learning system by adding two-way interaction features. The development is done by improving learning materials in the form of verb spelling and student interaction through answer cards. During the learning process with the robot, students showed interest in the robot's motion capabilities and the audiovisual material displayed. Subjects paid close attention to the robot, which led to a significant increase in the average correctness rate of typesetting from 25.55% during conventional learning to 63.86% with the robot. The standard deviation of robot learning was 26.54, while conventional was 18.47, indicating higher consistency with the robot. Factors such as subjects' memory performance and learning environment conditions may affect the inconsistency of the results. Robotic learning proved to be effective for subjects A and C, and moderately effective for subject B. Future research development plans include real-time data collection and processing with IoT as well as increasing the level of materials such as counting and social skills of money use.**

Keywords— Intellectual Disabilities, Fuzzy Logic, Audiovisual Intervention, Robotics, Special Needs Education

I. INTRODUCTION

Intellectual disability refers to the condition of individuals with below-average intellectual abilities, characterized by impairments in cognitive function, social skills, and adaptive behavior. According to the American Association on Intellectual and Developmental Disabilities, the impairments experienced cover various aspects such as thinking ability, academic learning to problem solving [1]. Thus, this situation requires appropriate support to help students with intellectual disabilities overcome their learning difficulties. To support the education of students with intellectual disabilities, special methods are needed in the teaching and learning process, as regulated in Law No. 20 of 2003 concerning the National Education System. One of these methods is the implementation of special schools and inclusive education at the any levels. In 2020, there were 2,250 special schools in Indonesia with 82,326 students [2]. The existence of Special School can increase the capacity of accommodating students with intellectual disabilities, but does not guarantee learning effectiveness due to different student characteristics, such as difficulty paying attention to long instructions and being easily distracted visually [3]. However, audiovisual distraction cannot be avoided directly, instead the utilization of audiovisual intervention facilities has a significant effect in improving the memory of students with intellectual disabilities related to daily life information, strengthening communication awareness and reducing aggressive behavior [4]. Therefore, there is a need for assistive technology that provides visually appealing interventions to increase students' attention.

Robots were chosen as learning aids for students with intellectual disabilities because they are able to increase their interest during the learning process. Students tend to make more eye contact with robots compared to human-based learning [5]. Assistive technology in the form of robots is used to support the learning of students with intellectual disabilities. If designed and implemented appropriately, this technology can increase their independence and participation. The use of robots shows that students with intellectual disabilities are more enthusiastic, with increased attention, imitation skills, and participation in social activities. Interaction with robots helps overcome the obstacles that often arise when interacting with humans [6]. Learning systems through interaction with learning robots are able to improve students' understanding of the material provided [8]. In addition, the learning process with repeated interactions is beneficial to improve understanding for students with intellectual disabilities.

II. LITERATURE REVIEW

A. Intellectual Disability

Intellectual disability refers to low general intellectual functioning and behavioral adjustment that occurs up to the age of 18. The determination of intellectual disability requires two criteria: a below-average intellectual level and an inability to adapt behavior to the environment. The classification of

Fig. 1. Learning Robot Prototype

intellectual disability is based on IQ and adaptive functioning, with the aim of determining the level of support required. There are four categories: mild (IQ 70-55) with difficulties in academic and social skills; moderate (IQ 55-40) with significant delays in conceptual skills and simple spoken language; severe (IQ 40-25) with very limited conceptual skills and minimal spoken communication; and profound (IQ <25) with very limited understanding of symbolic communication and complete dependence on others for daily care [7][8].

B. *Learning for Students with Intellectual Disabilities*

Students with intellectual disabilities require education tailored to individual needs, starting with identification through observation, interviews, informal tests and document review to understand their physical, intellectual and emotional conditions. This information is used to determine disabilities and plan follow-up assessments, covering academic ability, social and emotional development, and special barriers. The results of the assessment form the basis of an Individualized Education Program (IEP) tailored to the student's potential and needs, including short and long-term goals, learning methods and evaluation. [9].

C. *Quick Response Code*

Quick Response codes or QR code are two-dimensional matrix bar codes that store data and can be read by smart devices such as cell phone cameras. The code consists of black modules in a square pattern on a white background, and can encode text, URLs, or other data. The QR code system involves an encoder to encode data and a decoder to decode it, with versions 1 to 40 having different module configurations and maximum data capacities depending on the character type and error correction rate. The QR code structure includes four function patterns: finding patterns in three corners for position detection, separators as blank areas, timing patterns for alternating dark and light modules, and alignment patterns that contain format, version, data, and error correction information, ensuring the code can be read accurately [12] [13].

III. METHODOLOGY

A. *Subject Determination*

This study involved students with intellectual disabilities at the elementary school level at the Yayasan Pembinaan Anak Cacat (YPAC) Semolowaru special school in Surabaya. The students involved have a mild to moderate intellectual disability classification and do not exhibit tantrum behavior, facilitating direction and supervision. They have learned basic words and nouns, and will learn verbs. Given the different characteristics of each student, the intervention method must be tailored to their individual needs. Therefore, an initial observation was conducted to understand the condition of the students, whether hyperactive or passive, and ensure their readiness to follow all learning sessions. During the study, intensive consultations with each student's teacher were also carried out.

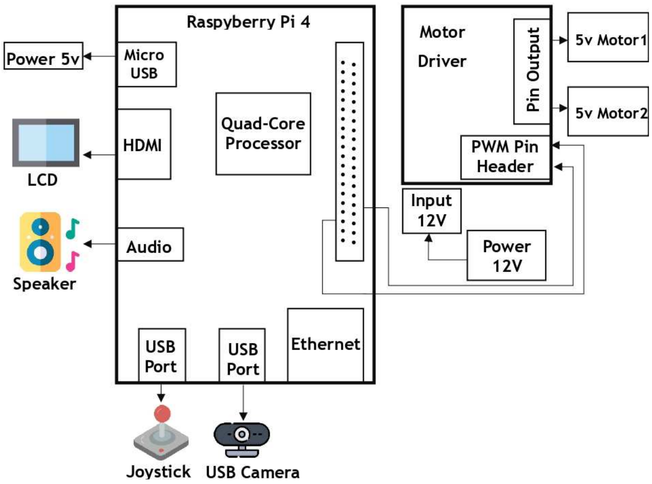

Fig. 2. Hardware Diagram of the Robot

B. *System Design of Robot*

The assistive technology that has been developed is a wheeled robot that uses Raspberry Pi 4 to control movement and other functions. This robot has two wheels powered by a 5V DC motor, with the direction of rotation and speed controlled through the L298N driver to maneuver forward, backward, and turn left and right. A joystick connected to the Raspberry Pi 4 via USB serves as an input tool to move the robot, with joystick movements changing the direction of rotation of the wheels. The robot is equipped with a camera connected to the Raspberry Pi 4 to scan the QR code on the card. The result of scanning the QR code allows the robot to display the corresponding video through the display screen and play audio through the speaker device, these features create an audiovisual intervention process in the learning of students with intellectual disabilities. These components synergize to attract students' attention and support their learning process interactively and effectively. The design of the robot and the connections between features are shown in Fig. 1 and Fig. 2.

The robot is equipped with a system that uses an algorithm to read QR codes of material cards containing verbs. When the card is near the camera, the QR code will be scanned, decoded, and the results matched with the data in the database. If they match, the robot will display video and audio through the display screen and speakers. In previous research, a similar system was used for interaction with students with intellectual disabilities, but it only provided predefined materials without interactive features. In this research, the system has been enhanced with the addition of an answer feature, allowing for two-way interaction between the robot and the student. The learning process begins when the student scans the QR code on the material card, then composes the answer card which is also scanned by the robot. The results are checked in database to display video and audio according to the answers given by the student. For clearer flow visualized through fig. 3.

C. *Assessment System Design*

The software designed for learning outcome assessment applies a fuzzy logic system to analyze learning outcome data

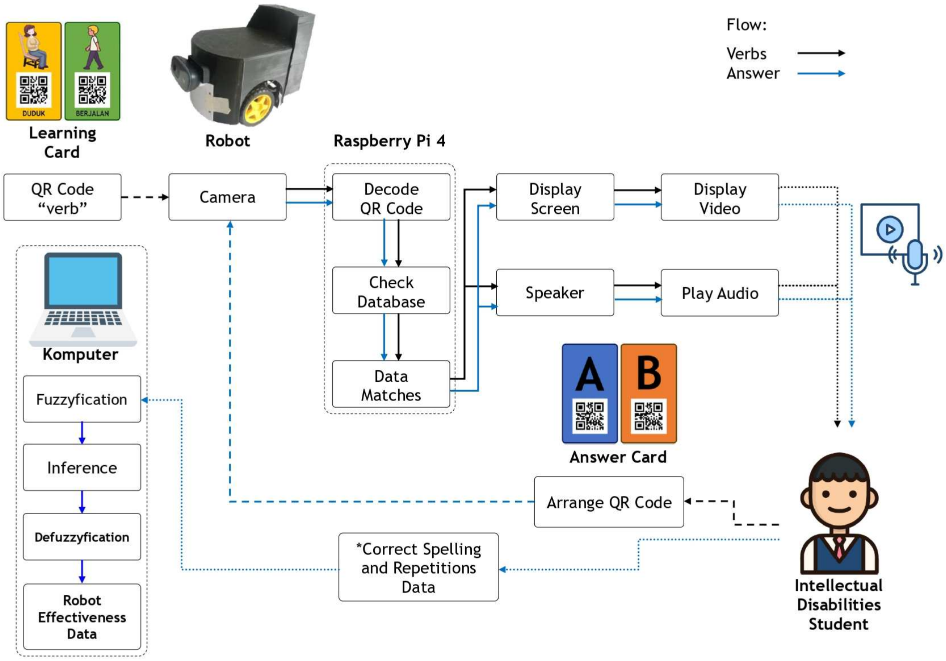

Fig. 3. System Diagram of the Robot

with a robot. The output of this fuzzy system ranges from zero to one and is used to evaluate the level of understanding as well as the effectiveness of learning. The assessment of understanding is based on the accuracy level and frequency of repetition, with degree of membership and membership functions shown in Table I. The results of these two aspects are processed based on certain rules to produce a decision regarding the student's understanding (poor, moderate, or good understanding).

Furthermore, the effectiveness level of learning with robot is assessed based on the understanding level and improvement level that tested as well as the learning outcomes between the pre-test and post-test, with degree of membership and membership functions shown in Table II. The results of these two aspects are processed to produce a decision regarding the effectiveness of robot learning (less, moderate, or effective).

D. Robot Testing

The robot was tested to assist the learning process of students with intellectual disabilities by teaching spelling words, involving a teacher or companion who prepares material cards containing basic verbs and verbs with affixes. Learning consists of three sessions: a pre-test to test students' initial knowledge through conventional methods, a learning session with the robot that is divided into basic and affixed verb learning stages, and a post-test to test students' cognitive abilities in remembering spellings. In the robot learning session, the material cards were scanned by the robot which then played the intervention video and helped students to organize the letters through display and sound. An example of a word taught is "MENULIS," where the robot scans the word, plays a video showing the writing ilustration, and helps the student arrange the letters. Evaluations were conducted after each session to assess the level of understanding and learning effectiveness, and all data was analyzed using a fuzzy logic system to determine the effectiveness of the robot in the learning process of students with intellectual disabilities.

TABLE I. FUZZY RULES FOR UNDERSTANDING LEVEL OF SUBJECT

Rule	Accuracy Level	Frequency of Repetition	Understanding Level
1	Low	Repeatedly	Poor
2	Low	Sometimes	Poor
3	Low	Once	Poor
4	Medium	Repeatedly	Poor
5	Medium	Sometimes	Moderate
6	Medium	Once	Moderate
7	High	Repeatedly	Moderate
8	High	Sometimes	Good
9	High	Once	Good

TABLE II. FUZZY RULES FOR THE EFFECTIVENESS OF LEARNING WITH ROBOTS

Rule	Improvement Level	Understanding Level	Effectiveness Level
1	Worse	Poor	Less
2	Worse	Moderate	Less
3	Worse	Good	Less
4	Same	Poor	Less
5	Same	Moderate	Moderate
6	Same	Good	Moderate
7	Better	Poor	Moderate
8	Better	Moderate	Effective
9	Better	Good	Effective

IV. RESULT AND DISCUSSION

This research uses material card and answer card. The material card measures 18 cm x 10 cm with a QR code of 6.5 cm x 6.5 cm, while the answer card measures 8 cm x 5 cm with a QR code of 3.5 cm x 3.5 cm. The test objectives were to assess the detection capability of the QR code by the robot camera and determine the optimal distance for effective

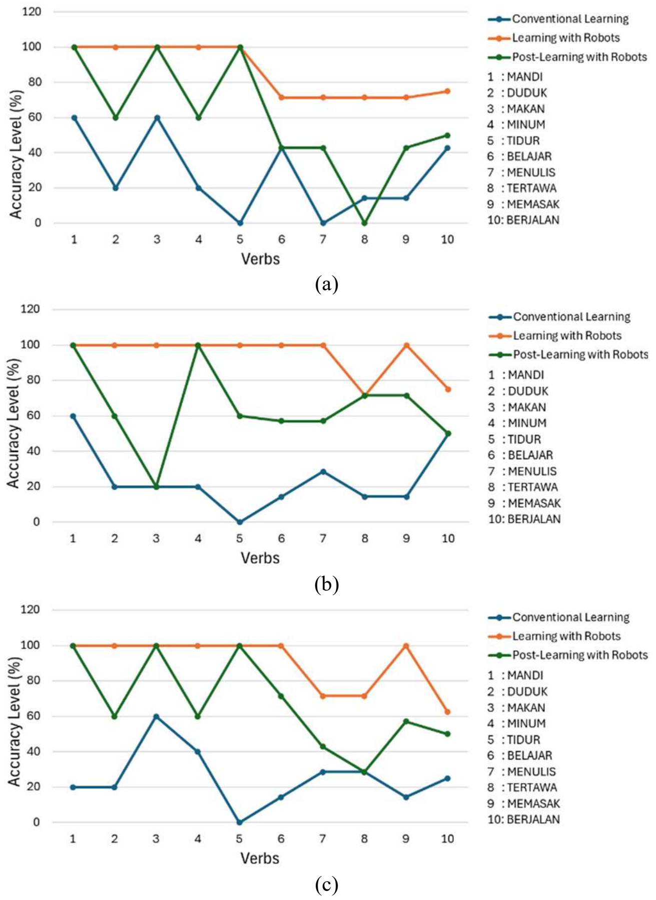

Fig 4. Accuracy Level (a) subject A (b) subject B (c) subject C

TABLE III. RESULT FUZZY UNDERSTANDING LEVEL SUBJECT A

Rule	Accuracy Level (%)	Frequency Repetition	Understanding Level	Point
MANDI	100	2	Good	3
DUDUK	60	2	Moderate	2
MAKAN	100	1	Good	3
MINUM	60	1	Moderate	2
TIDUR	100	2	Good	3
BELAJAR	42.86	4	Poor	1
MENULIS	42.86	4	Poor	1
TERTAWA	0	5	Poor	1
MEMASAK	42.86	4	Poor	1
BERJALAN	50	4	Poor	1
Total				**18**

scanning. Trials were conducted with distance variations from 10 cm to 100 cm, increasing every 10 cm, with three repetitions for each card type in a room with the same lighting. The learning robot is also equipped with motors and wheels that allow it to move forward, backward, turn left, and turn right according to the joystick movement. These movements aim to interest the subject in learning and provide entertainment. Through mobility features, the robot can approach QR codes as part of the learning process. Testing the robot's motion capabilities is done to assess its success rate in performing various types of movements. The Pulse Width Modulation (PWM) value is set and adjustable. For forward and backward movements, both main wheels move

TABLE IV. RESULT FUZZY UNDERSTANDING LEVEL SUBJECT B

Rule	Accuracy Level (%)	Frequency Repetition	Understanding Level	Point
MANDI	100	2	Good	3
DUDUK	60	3	Poor	1
MAKAN	20	2	Poor	1
MINUM	100	2	Good	3
TIDUR	60	3	Poor	1
BELAJAR	57.14	5	Poor	1
MENULIS	57.14	4	Poor	1
TERTAWA	71.43	5	Moderate	2
MEMASAK	71.43	4	Moderate	2
BERJALAN	50	5	Poor	1
Total				16

TABLE V. RESULT FUZZY UNDERSTANDING LEVEL SUBJECT C

Rule	Accuracy Level (%)	Frequency Repetition	Understanding Level	Point
MANDI	100	2	Good	3
DUDUK	60	2	Moderate	2
MAKAN	100	1	Good	3
MINUM	60	2	Moderate	2
TIDUR	100	2	Good	3
BELAJAR	71.43	4	Moderate	2
MENULIS	42.86	3	Poor	1
TERTAWA	28.57	4	Poor	1
MEMASAK	57.14	3	Poor	1
BERJALAN	50	5	Poor	1
Total				19

simultaneously. For right turn and left turn, only one wheel moves, making the robot turn with the axle on one wheel: right turn with the axle on the left wheel and left turn with the axle on the right wheel.

A. Subject Learning with Robot

Testing the robot on the subject was conducted in three stages of learning. The first stage was a conventional learning session, where the subject learned to recognize verbs with the help of researchers and assistants. This session was conducted face-to-face like in class, with each verb introduced one by one, letter by letter, until ten words were learned. After the learning is complete, the subject arranges the letters independently to form the specified verbs. The second stage was a learning session with the robot, where subjects were introduced to the robot's features such as camera, video, audio, and motion. Learning began once the subject was ready and was conducted flexibly, with repetition until the subject reached a correctness rate above 60% or until the subject felt bored. The third stage was a post-learning session with the robot, where subjects were given a break before composing words without the help of the robot. The instructions were in the form of illustrative pictures of verbs, and the subject arranged the letters into the target word.

TABLE VI. IMPROVEMENT LEVEL OF SUBJECT

Verbs	Subject		
	A	B	C
MANDI	3	3	3
DUDUK	3	3	3
MAKAN	3	2	3
MINUM	3	3	3
TIDUR	3	3	3
BELAJAR	2	3	3
MENULIS	3	3	3
TERTAWA	1	3	2
MEMASAK	2	3	3
BERJALAN	1	2	3
Total	**24**	**28**	**29**

TABLE VII. EFFECTIVENESS LEVEL OF LEARNING ROBOT

Subject	Understanding Level	Improvement Level	Effectiveness Level
A	18	24	Effective
B	16	28	Moderate
C	19	29	Effective

B. Learning Result Data

After conducting three stages of testing and data collection, results of the word arrangement were analyzed to check the position and order of the letters, resulting in a percentage of the correctness of the letter arrangement for each subject. The data was processed using a fuzzy scoring system to measure the comprehension level and effectiveness of the learning robot. The level of comprehension is calculated from the level of spelling correctness and the number of repetitions of the material, and then categorized into poor understanding, moderate understanding, and good understanding, with points 1, 2, and 3 respectively shown in Table III, IV and V. The effectiveness of robot is measured by level of improvement and level of understanding, with improvement categorized into worse, same, and better, converted into 1, 2, and 3 points respectively shown Table VI.

Subject A, a 22-year-old with difficulty recognizing random letters and limited mobility, participated in learning in three stages: conventional, with a robot, and post-learning with a robot. In conventional learning, the subject learned by reciting letters one by one with a companion and was tested by arranging random letters. Learning with the robot started with feature recognition and scanning of the material cards by the robot's camera. Although the learning video was too fast, the subject managed to arrange the words with the help of rescanning. After a break, the subject was tested by arranging letters without the help of the robot material. Subject B, a 15-year-old with the intellectual ability of a five-year-old and a tendency to throw tantrums, participated in conventional learning with a companion who helped with letter formation. In learning with the robot, the subject focused on the video material and the robot with no response to joystick bids. After a break, the subject was tested on composing words from the material cards without additional assistance, successfully composing ten verbs. Subject C, aged 11 years old with good communication skills but difficulty composing letters, learned conventionally with a companion and researcher. After taking a break, the subject learned with the robot, paying attention to the video and audio and composing letters according to the material scanned by the robot. Despite the need to re-scan several times, the subject managed to compose ten verbs. After the break, the subject was tested by arranging letters without additional assistance, and successfully arranged ten verbs.

TABLE VIII. TABLE TYPE STYLES

Data	Conventional Learning Result	Robot Learning Result
Total Data	30	30
Mean (%)	25.55	63.86
Standard Deviation	18.47	26.54

The use of the learning robot feature was based on the test results to determine the optimal conditions of the tool. The material cards and answer cards were designed with attractive colors and relevant illustrations to increase the subject's interest. The material cards, which were larger and had pictures, aimed to trigger the subject's memory of frequently performed activities, while the smaller answer cards facilitated typesetting. QR code scanning tests were conducted at various distances, from 10 cm to 100 cm, with three repetitions for consistency of results. The results show that the material cards can be scanned well at a distance of 20 cm to 90 cm, while the answer cards are optimal at a distance of 10 cm to 50 cm. Too close or too far distance results in scanning failure as the QR code details are not read well.

The video and audio features of the robot, which displays letters and pronounces them through speakers, successfully attracted the subjects' attention. Meanwhile, the robot's motion feature, which relies on two main wheels and a stabilizing wheel, was tested at various speeds. At a pwm setting of 70, the speed of the robot surprised the subject, so the researcher lowered it to pwm 30 to increase the subject's comfort, then showed interest in trying to move the robot. When the robot successfully scanned the QR code of the material, the screen displayed a video illustration according to the material card and recited the letters through the robot's speaker. These video and audio features successfully attracted the subject's attention. The motion feature of the robot, which uses two main wheels and a small stabilizing wheel, was initially tested with a PWM of 70 but was adjusted to a PWM of 30 for the convenience of the subject, who showed surprise at the initial fast movement.

Each stage of learning and testing followed by the subject resulted in a word composed according to their individual abilities. The graphs displayed in Figures 4 show that learning with the robot tends to produce a higher correctness rate compared to the conventional method. In Subject A, although there was one word that was better in the conventional learning, in general the robotic learning achieved 100% correctness compared to the maximum value of about 60% from the conventional method. Subject B showed a similar pattern, with higher robot learning scores, although there were some words with similar scores between the two methods. Subject C also showed a trend towards better results in robot learning, except for the word "tertawa" which had the same correctness value.

The duration of time was not considered in the research to focus on the subjects' motor skills, which vary and affect letter arrangement. This research emphasizes the intellectual ability of the subjects rather than time. The results indicate that the accuracy levels might be the same between the two methods, but the correct letter positions could differ significantly, influenced by factors such as the subjects' memory performance and the learning environment. The learning environment has a significant impact on the subjects' focus. Subject A studied at home with a noisy alley that disrupted concentration due to many cats. Subject B studied at a roadside stall with vehicle noise disturbances and attention diverted by siblings. Subject C studied at home with a grocery store, facing disturbances from buyer noise and siblings. Ideally, learning for students with intellectual disabilities requires a conducive environment to maintain focus, and this research shows the need for extra effort to create optimal learning conditions.

The assessment of understanding levels is conducted using fuzzy logic. For instance, subject B successfully arranged the word "MANDI" with 100% accuracy after two repetitions. The repetition and accuracy data are processed using fuzzy logic to determine the subject's understanding level of the word. This process is applied to all words arranged by subject B, resulting in a total score converted to show the overall understanding level. To measure the robot's effectiveness in improving the subject's abilities, the understanding level and improvement data are processed. The total improvement points for subject B are 28 points. This data is used to evaluate the robot's effectiveness, indicating that the robot is generally effective in improving the intellectual abilities of subjects A and C and is at an adequate level for subject B shown in Table VII.

Based on data from Table VIII, there is a significant difference in the average accuracy rate between conventional learning and learning with a robot. Conventional learning has an average accuracy rate of 25.55, while learning with a robot reaches an average of 63.86. This indicates that using robots in learning can increase the interest and focus of students with intellectual disabilities, thus leading to better learning outcomes. Interactive robots are capable of maintaining students' attention longer, providing consistent feedback, and making the learning process more enjoyable. However, the standard deviation of learning outcomes with robots is 26.54, higher compared to 18.46 in conventional learning. This indicates that although the average accuracy is higher with robots, there is greater variation in the results. This variation can be attributed to differences in the learning environment between the two methods. An ideal environment can disrupt the subjects' focus, affecting the consistency of learning outcomes.

Conclusion

The use of robot intervention technology specifically designed for students with intellectual disabilities can significantly enhance their learning abilities, particularly in arranging letters for verbs frequently used in daily activities. The research results show a significant increase in letter arrangement accuracy, from 25.55% with conventional learning methods to 63.86% with the use of robots. The smaller standard deviation in learning with robots (26.54) compared to conventional learning (18.47) indicates more consistent accuracy levels. Inconsistent learning outcomes can be influenced by various factors, such as the subjects' memory performance on the learning material and can also be affected by the environmental conditions during learning. The assessments conducted show that learning with robots is effective for subjects A and C and sufficiently effective for subject B. Future research development plans include real-time data collection and processing with IoT as well as increasing the level of materials such as counting and social skills of money use.

Acknowledgment

This study was partially funded by BME Department ITS Research Program 2024 under contract number: 1065/PKS/ITS/2024. Technical supports were also from SLB YPAC Surabaya. The authors would like to express grateful thanks to both institutions, for funding and technical support.

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