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## **RoboDIL: A Robotic Tool to Aid the Pedagogy of Students with Dyslexia**

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(Article history: Received December 14, 2025; Received in revised form January 10, 2026;

Accepted February 19, 2026; Available online June 15, 2026)

**Abstract:** Dyslexia is still highly complex in the national educational environment, especially in elementary school classes. This situation of not offering people with Dyslexia a safe and inclusive academic environment is responsible for causing attention deficit disorders and even school dropouts. In search of solutions to this problem, information technology is utilized as a valuable resource to aid in this endeavor. Thus, the resource seen in this work, which combines Information Technology with robotics, gamification, and a therapeutic vision through applications based on the psychology of form, helps to provide a playful and inclusive resource in the educational environment.

**Keywords:** Dyslexia; Robotics; Information Technology

### **1. Introduction**

Dyslexia is a cognitive problem characterized by difficulty understanding written language, which slows reading speed and impairs recognition of two-dimensional symbols and shapes. About 5-10% of the world's population has Dyslexia [1], but at preschool age, there are cases of up to 20% among children with this problem [2]. Students with Dyslexia tend to experience more significant difficulties during the elementary school phase, and the damage caused by this dysfunction is more severe in the literacy process [3].

Some studies indicate that the brains of people with dyslexia process information differently from those of individuals without Dyslexia [4]. As most educational resources for literacy are geared toward serving students without this dysfunction, there are difficulties for students with Dyslexia in adapting to standard literacy proposals. The country's education systems still cannot provide an educational environment for students with Dyslexia at any level of education. The curricula, methods, techniques, technologies, and educational resources are not tailored to the specific needs of these students unless there is room for education that is referred to as "special education" [5] [6], which is not carried out within an inclusive perspective.

This work presents a platform development aimed at promoting inclusive and therapeutic education through the use of information technology (IT), called RoboDIL. It represents an example of educational robotics for people with Dyslexia, focusing on movement, depth, distance, and spatial observation, based on the concept of three-dimensionality [7], to be applied in learning for people with Dyslexia. The basic idea defines its use within a gamification model.

The platform was taken and tested in three elementary school classes at a municipal school between 2022 and 2024. The primary motivation was to verify whether the pedagogical characteristics included in the development of RoboDIL would be suitable for this tool, which is to assist both dyslexic and non-dyslexic students in reading texts.

RoboDIL can be used for simple literacy training for individuals with Dyslexia and for improving the cognitive, letter, syllable, and word identification skills of those with reading disabilities. It can also be used in therapeutic settings to support speech therapy professionals. It can reduce rejection in this field of learning. This paper is divided into an introduction, an overview of related works, application and methodology descriptions, the platform development description, tests, a discussion about results, and a conclusion.

## 2. Related Works

### 2.1. About Dyslexia

Dyslexia was a term coined in 1872, reinforced in Hinshelwood's 1917 work, and identifies people without cognitive intelligence problems who have difficulty reading and writing, confusing letters, symbols, and words, associated with a visual memory problem due to a dysfunction in an area of the brain linked to language [8]. According to the National Institute of Neurological Disorders and Stroke (NIH [9]), the definition of Dyslexia is a learning disorder characterized by brain changes that affect reading. People with Dyslexia read at lower levels than expected, despite having average intelligence.

Within genetics, it was noted in [10] that Dyslexia is associated with a specific set of chromosomes (chromosomes 6 and 15) and genes (DYXC1, KIAA0319, and DCDC2) that are found in individuals with this condition. In [11], the altered cortical areas in children with Dyslexia were recognized as necessary in the reading process. The classification of types and subtypes of Dyslexia, since 1973, follows a division originating from [12] on reading and interpretation, highlighting the following clinical categories of Dyslexia: Profound Dyslexia, in which the person has difficulty with both phonemic decoding and semantic decoding; Phonological Dyslexia, in which the person has difficulty in phonemic decoding, with impaired word visualization; and Surface dyslexia, in which people have visual problems reading or establishing the correct route of reading.

This classification considers the similarities between phonetic and phonological dysfunction, noting that phonological Dyslexia has the highest incidence among people with Dyslexia, with a percentage ranging from 67% to 70% of dyslexia cases identified in

individuals in the early years of school [13][14]. Phonetic dysfunction is when people confuse phonemes, letters, or syllables when reading or listening to a word. There is visual dyslipidemia dysfunction, in which people have more difficulty reading, obscuring the peripheral vision of terms within a sentence.

## *2.2. Educational Approaches for Dyslexia*

There are two most commonly used methods to assist in the pedagogy of people with Dyslexia:

- Multisensory approach, based on phono-articulatory awareness or phoneme visualization, in which people with Dyslexia can decode letter sounds and transform them into writing, performing the conversion to phonemes/graphemes [15] [16].
- The phonics approach, which applies graph-phonemic correspondences to develop meta-phonological skills, is based on the relationship between sounds and letters. This method begins with the sounds of vowels and consonants, pronounced in isolation, and combines the consonants with each vowel to form syllables [5] [16].

These approaches aim to empower people to read and understand texts, seeking to meet the social inclusion demands of these individuals [5]. In [17], the use of electronic games as a valuable tool in teaching and learning phonics-based literacy systems was addressed, with an eventual adjustment aimed at students with Dyslexia. In [18], it was observed that people with Dyslexia can improve their learning when their senses are engaged in a three-dimensional approach. It was also confirmed in work [7], in which it was observed that students with Dyslexia have a three-dimensional perception. One field of research in the area of supporting people with Dyslexia is the construction of educational resources. With IT, those implement methods based on three-dimensionality to reduce reading difficulty [19].

## *2.3 Inclusive Education with IT*

Numerous studies demonstrate the positive applications of robotics in assisting individuals with reading and understanding difficulties, utilizing the socio-constructivist theory of Educational Robotics, as well as the integration of Gestalt Therapy [7] [16] [20]. In some cases, the Gestalt Therapy approach (in education) shows the student/teacher relationship as a social/dynamic construct in which the student is prepared to obtain new knowledge, such as robotics [20]. An example of this approach is the development of resources to test how three-dimensionality aids in the learning process of individuals with Dyslexia.

In [21], a robotics approach was applied to students with learning difficulties, including Dyslexia. This approach incorporated elements of Gestalt Therapy, with a therapeutic and educational bias, offering an inclusive perspective on the students. In [22], the constructivist approach was applied to a game called SpaceEduc, designed to improve the reading

performance of students who struggle with this task. Also, in [23], the use of a video game that applies various methodologies to help dyslexic people read is demonstrated.

In [24], the Educational Robotics approach was applied to improve the teaching scenario for students with learning or reading difficulties. The focus was on determining whether a physical robot would serve the intended educational purpose. The benefits and disadvantages of using a robot for literacy cases were observed. A study was conducted in [25] on the approach of robotic tools to teaching people with special needs, utilizing several methodologies. It was observed that robots are more effective in addressing students' difficulties than other forms of IT.

### **3. RoboDIL Architecture**

RoboDIL is an educational resource built from simple robotic components and easy-to-implement programs. RoboDIL was developed to assist people with dyslexia or reading difficulties, bringing pedagogical and therapeutic aspects [24]. The approach chosen was based on the psychology of form, as seen in [21] [26], contributing to the definition of the platform/environment format and the activities associated with RoboDIL.

The goal of this platform is to work on the elements of concentration and interaction in tasks, with the aid of IT resources, to provide a variety of content absorption or ways of learning, contributing to the social inclusion of students with Dyslexia and reducing the reading rejection rate of these individuals [21]. RoboDIL proposes to offer a multifunctional yet straightforward approach to assisting the learning of people with Dyslexia based on the concepts seen in [7] [18], focusing on the ideas attributed to three-dimensionality, motion perception, and spatial vision.

The concept of three-dimensionality used was with the idea of capturing movement (within a plane), in the use of color (for a depth analysis), and in the shape of the block in which the symbol sought (to be the width). RoboDIL was designed to meet the needs of support for multisensory and phonics methods to assist dyslexic people. In the sensory method, the symbols are identified through visual stimuli, such as seeing the sign on a poster and looking for it on the Board. In the phonetic approach, the applicator verbalizes the phoneme, making the target user use RoboDIL to correlate what was heard with the symbol on the Board.

#### *3.1 Robodil Architecture*

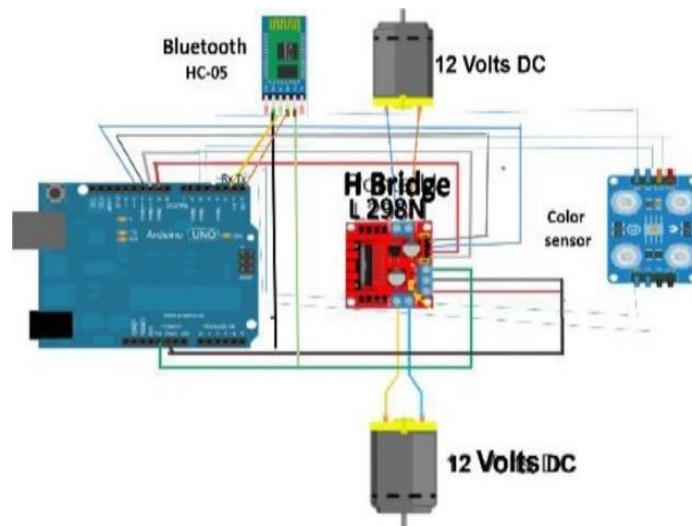
RoboDIL has three primary modules: a Robot, which runs through a Board (formed by letters, syllables, words, numbers, or other symbols that may be necessary), and an Application, which controls the Robot by moving it to a position on the Board. The objective is to identify symbols, or form syllables or words, according to the degree of complexity

provided to the target user. The letters or words to be searched for can be passed on via a poster, digital panel, or auditory stimulus.

### 3.1.1 Robot Module

The Robot module has a chassis, two DC motors, two main wheels, a support wheel, a device to control the speed of the motors (H-bridge), a color identification sensor, a microcontroller, and a *Bluetooth* module. The chassis houses the microcontroller and other components, is low-cost, and is feasible for all elementary and high schools [27]. The Robot's microcontroller is the ATmega328P, used on the Arduino UNO R3 interface [27].

Among some justifications for choosing this type of microcontroller and interface, there is the fact that it has a low cost, with the ability to handle the selected sensors and communication devices, has an accessible programming environment, requires minimal knowledge of microcontrollers, and is easy to understand and use. The color sensor is a TCS230 RGB type, capable of identifying 256 color hues to read the color associated with the block on the Board [27]. The communication module, which uses the *Bluetooth* protocol, is the HC-05; both receive and send commands, allowing the mobile device with the Application to "talk" to the Robot and vice versa [27]. Figure 1 shows the basic scheme of the electronic connections of its parts.



**Figure 1.** Electronic wiring diagram of the Robot, with its components: DC Motors, MCU AVR in Arduino Interface, H Bridge L298N e Color Sensor TCS230 RGB.

### 3.1.2 Board Module

The Board is designed as a carpet, with the symbols (letters, phrases, or numbers) on a different colored block. The Robot moves over it and positions itself on one of the blocks. When the Application activates the color sensor, the HC-05 transmits the captured color to

the Application. The assembly of each Board and the choice of letters were guided by [28], which found that in surface dyslexia, there are more significant difficulties associated with reading and confusion of graphic symbols, such as /m/ with /n/; /j/ with /i/; /e/ with /o/, /p/ with /b/; and in deep Dyslexia, one confuses the sound of phonemes, such as, for example, /d/ with /b/; /d/ with /p/ and /m/ with /n/,

RoboDIL proposes to work with both surface and deep Dyslexia. For surface dyslexia, the symbol is passed on visually by the applicator, and the user has to look for the graphic correlation between what is being seen and what is on the Board. In the case of profound Dyslexia, the applicator verbalizes the phoneme to be searched. The user then tries to position the Robot on the symbol on the Board that he understood. In this case, there is an auditory correlation with the graphic logo on the Board.

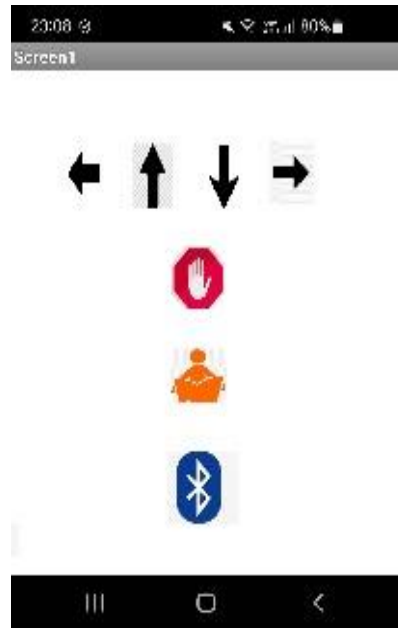
Another factor that was considered is that, according to [28], about 70% of the letters used in books or school reading material are cursive style, lowercase, and appear in black colors. Based on this orientation, two 12-position panels were designed for practical applications, with lowercase letters printed in black and Helvetica print font in a style similar to simple cursive. The boards for the sessions were handmade with rectangular paper blocks, measuring 20x14 mm, with a thickness of 2 mm, of various colors, with a matrix of blocks of 4x3 columns/rows. The letters were printed in black ink, like cursive, lowercase, with 300 pts size Helvetica type. The two types of boards used are shown in Figure 2.



**Figure 2.** Boards used in the test sessions were made from plain cardboard.

### 3.1.3 Application Module

The Application was developed in the MIT App Inventor language for the Android operating system (OS), as this is the most widely used OS in national schools. It handles *Bluetooth* communication with the Robot to send movement commands and the "read" command from the color sensor. These commands are graphic symbols of common knowledge, which do not generate doubts about meaning. The primary target audience is composed precisely of people who can confuse letters or numbers. The Application screen, with the controls, can be seen in Figure 3.

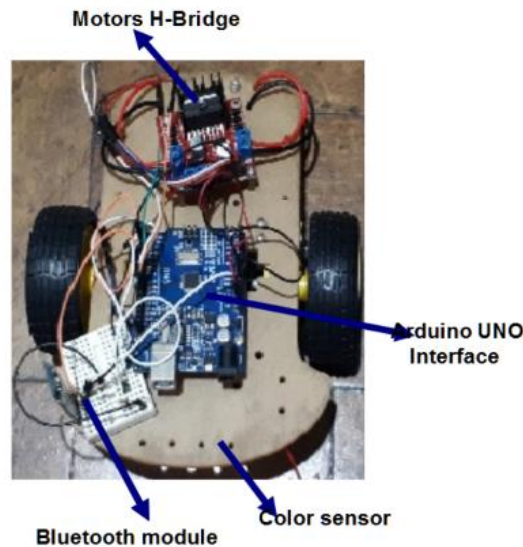


**Figura 3.** Screen of the RoboDIL app, developed at MIT App Inventor, with movement and reading symbols.

#### **4. RoboDIL Configuration**

RoboDIL was adapted to be applied in person in three different classes at a municipal school between 2022 and 2024.. All three classes were elementary grade, composed of 25 students in the first, fifteen in the second, and fifteen in the third, with the ages ranging from ten to fifteen years old. Figure 4 shows an example of RoboDIL assembly, used in these tests.

It was found that the average rate of dyslexic students in these classes was 30%. For the inclusion and protection of students with Dyslexia, all application sessions involved all students, with no clear differentiation between them. Only the teachers and the administrators knew who the students with Dyslexia were. Complying with the requirements of the school's Ethics Board, in applying RoboDIL in each class, the students' participation was voluntary, with all willing participants obtaining approval from their guardians, teachers, and other educational bodies through specific consent forms for this educational activity.



**Figure 4.** A RoboDIL assembly, used in tests in a municipal school.

#### *4.1 Initial settings*

RoboDIL was implemented according to a free game philosophy, in which no winners, losers, or rankings (ratings) are sought, meaning it does not utilize all the gamification concepts [29]. It has the playful objective of creating a person to place the Robot on one of the blocks on the Board, whose letter or symbol is passed to him by an enforcer. Each block has a letter (or another character) linked to a color. At the end of the positioning, the user triggers the color sensor, which returns the color identification, allowing the application to display the letter or symbol corresponding to the Robot's position. In this way, it is possible to verify whether the letters, symbols (or a combination of them) chosen by the user with the Robot-Tablet-Application correspond to what has been communicated, either manually or orally (in specific cases of phonological Dyslexia). The symbol chosen by the user is displayed on the mobile device's screen so that it can be compared with what was passed by the applicator.

##### 4.1.1 Color Sensor Calibration

The TCS-320 color sensor receives three signals to identify a given color, working in RGB signal pickup. With the frequency pickup for the tone of RED (R), GREEN (G), and BLUE (B) in each position where the sensor is placed, the analysis of these RGB signals can determine a distinct color. As seen, the letters are associated with the colors of each block so that: blue =n; red =a; light yellow =m; dark yellow = j; white =0; green = e; light blue =u; yellow =j; orange =p; light green = d; pink = b and gray = q. Therefore, a calibration of the color sensor was necessary, considering that the RoboDIL is to be used in environments with different incidences of light, which can be natural or artificial, and can modify the analysis of the color being analyzed.

In hardware, the sensor was calibrated, via jumper, with a 2% adjustment to capture most of the irradiation of the blocks without interference and a filter. As said, this was because in each session, there could be variations in light interference, either by the time of day or by the light incident on the window and other situations. Besides the hardware adjustment, it was essential to limit the data captured by the sensor for each block. Two hundred fifty measurements were taken for each color block, during three consecutive days, in different locations and times, such as: outdoors from 10:00 to 12:00 (MMO); outdoors from 16:00 to 18:00 (AMO); indoors from 10: 00: 00 to 12:00, with natural light (MNI); indoors from 10:00 to 12:00, with artificial light (MAI); indoors from 16:00 to 18:00, with natural light (ANI); and the indoors from 16:00 to 18:00, with artificial light (AAI).

These measurements produced a spreadsheet with the captured RGB values for each block on the plate. This data was submitted to a classification software (used only once) to identify the maximum and minimum values of the RGB signal used by the application, thereby increasing the certainty of the color identification for the block (and its associated letter). Based on the completed spreadsheet, the classification software was built for each block, using only lines with values close to the median values, disregarding the values far from the norm (that had a difference equal to or greater than 10%), the frequency limits (R, G, or B), inserted into the Application.

In Table 1, you can see an example of the measurement spreadsheet submitted to the classification software, specifically for the yellow block (letter 'j'). In Table 1example, the values that identify the yellow block are in the range: R=51 to 53, G=65 to 69, and B=88 to 90. It means that when the color sensor detects these values, RoboDIL associates them with the letter 'j.' With the definition of these limits, the Application can receive the data from RoboDIL and identify the chosen letter more accurately. The margin of error in color identification, with the 250 measurements, stabilized at 2%, which means that for every 1000 block color measurements, 20 can indicate an incorrect height.

**Table 1.** Example from the classification software for the Yellow color ('j' letter).

<u>R</u>	<u>G</u>	<u>B</u>	<u>R</u>	<u>G</u>	<u>B</u>	<u>R</u>	<u>G</u>	<u>B</u>	<u>R</u>	<u>G</u>	<u>B</u>	<u>R</u>	<u>G</u>	<u>B</u>	<u>R</u>	<u>G</u>	<u>B</u>
<i>Day 1 (Average Measures from 1 to 87)</i>																	
MMO			AMO			MNI			MAI			ANI			AAI		
52	65	88	51	66	90	52	65	90	51	69	89	53	65	89	51	69	89
<i>Day 2(Average Measures from 88 to 183)</i>																	
MMO			AMO			MNI			MAI			ANI			AAI		
52	65	88	53	65	89	52	65	89	52	65	89	52	65	88	51	67	88
<i>Day 3 (Average Measures from 182 to 250)</i>																	
MMO			AMO			MNI			MAI			ANI			AAI		
52	65	88	52	65	90	52	65	89	52	65	88	52	65	88	51	67	88
<b>Result: Letter' j',Yellow Color - R: 51 a 53 G: 65 a 69 B: 88 a 90</b>																	

#### 4.1.2 Analysis parameters

To mitigate the quantitative bias in the analysis of RoboDIL, parameters were selected to verify the platform's adherence and evolution throughout the sessions. These are: Search and confirmation time; Time counting between seeking the symbol presented by the applicator (manual, digital, or oral) and confirming the choice; and The number of hits on symbol choice represents a hitting statistic.

In addition to quantitative analysis, qualitative data were also collected to observe aspects of reading recovery. In the first and second classes, sessions were held on one day of the week, for each week of the school year, during school hours, twice a day, 50 minutes at a time, totaling 1 hour and 20 minutes per session. In the third class, due to scheduling issues, the sessions were held only with two face-to-face sessions.

### 5. Testing Results

#### 5.1. Sessions preparation with RoboDIL

The sessions took place in the morning, lasting 1:20. The students' participation was voluntary. Still, all participated, obtaining approval from guardians, teachers, and educational agencies, with specific consent for this educational Application. The Application was installed in a Multilaser M7 Tablet owned by the applying teachers and in the students' cell phones with the Android operating system. Two Robots and two Boards were built.

In each session, random symbols were chosen, which were searched for either as a group or individually. For the sensory sessions, the applicator held up a poster, in A4 format, with the letter printed in Helvetica, lowercase, and 300 pts. For the phonics method session, the applicator spoke the letter aloud for 10 seconds, after which the student began searching for the board symbol using the Robot. The search time was measured with a standard stopwatch.

#### 5.2 Results achieved

In the results, the number of sessions with RoboDIL applied in the year, the number of students who participated, the average search time in the sensory and phonic models, and the average number of hit attempts in the classroom were verified. The results are presented in Table 2, which includes data from students without Dyslexia who participated, and in Table 3, which includes data from students with Dyslexia. The average search time, indicated in both tables, was obtained in minutes.

Another quantitative measure obtained was a check on text reading time. The objective of this measurement was to observe whether the sessions with RoboDIL improved the reading of more complex texts, comparing the data obtained between students with and without

Dyslexia. The results seen in Table 4 present the time spent by students reading before the sessions and after two weeks following the last session with RoboDILfor, all students. The time was measured in minutes. The text was from a general history textbook, about five paragraphs long.

**Table 2.** Result of session data for students without Dyslexia (time measured in minutes).

Class	Persons without Dyslexia	Sessions per year	Average search time, <sup>1</sup>	Average search time, <sup>2</sup>	Average Attempt /Hits
Elementary School 1	17	40	9	7	5T/3A
Elementary School 2	9	32	10	10	5T/3A
Elementary School 3	10	12	14	8	5T/4A

1: Sensory Method; 2: Phonics Method

**Table 3.** Result of session data for students with Dyslexia (time measured in minutes)

Class	Persons with Dyslexia	Sessions per year	Average search time, <sup>1</sup>	Average search time <sup>2</sup>	Average Attempt /Hits
Elementary School 1	8	40	17	10	5T/2A
Elementary School 2	6	32	18	15	5T/2A
Elementary School 3	5	12	21	10	5T/3A

1: Sensory Method; 2: Phonics Method

**Table 4.** Data on the reading time of a text before and after sessions with RoboDIL

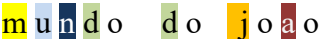
Class	Average reading time (min)			
	Students with Dyslexia		Students without Dyslexia	
	Beginning of the year	After the last session	Beginning of the year	After the last session
Elementary School 1	25	17	15	13
Elementary School 2	28	19	16	12
Elementary School 3	27	20	18	15

### 5.3 Discussion of the results

Based on the results, it was observed that at the beginning, the average time to find the letters was longer among the students with Dyslexia. Still, throughout the application time, the average time between the groups approached so that they were similar. In the last session, the difference in symbol finding and grasping time between the groups dropped from 50% (at the beginning) to 15%. It meant that a student without Dyslexia took 9 to 10 minutes, but

a student with Dyslexia took (at the beginning) 18 to 20 minutes and reduced it to 12 to 14 minutes.

Besides this, the applicators and teachers observed the following factors for this approximation of values: RoboDIL was identified as a friendly and fun tool. The feeling of a game without the criteria of ratings, but getting the letters right, made all students put more effort into the letter identification task. All the sessions included all the students, both those without Dyslexia and those with Dyslexia, which could be a negative factor. Still, they proved positive because the students with Dyslexia did not feel intimidated but challenged in the face of other students who got it right in less time and with more accuracy. Thus, they tried to match each other throughout the sessions, aiming to improve their perceptions. Over time, both the number of hits and the average search time decreased.

The students' report of how RoboDIL helped them in their reading is noteworthy. Regarding the reading exercise before and two weeks after the use of the last session with RoboDIL, there was, among the group of students with Dyslexia, a significant improvement in the reading conditions. In these informal reports, it was noticed that, in the letters, they had more difficulty understanding. The letter/color/movement factor had a vital relevance. For them, for example, the reading of an expression, such as: "mundo do joao", was seen as follows: 

That is, the students with Dyslexia, after the sessions with RoboDIL, could associate the relationship between color and letter in their minds, as well as remember the movements performed with the Robot on the Board to find the symbols. It demonstrated how the three-dimensional vision, made possible through RoboDIL, can be satisfactorily captured by students with Dyslexia.

## 6. Conclusions

RoboDIL can help students with Dyslexia develop their reading skills and help others who are struggling. It presents results related to inclusion, well-being, and improvement in reading, considered satisfactory by the applying teachers. Due to the small number of researchers involved, only one class per year was considered.

The results were repeated in different courses, encouraging the search for more collaborators to apply the resource in more schools and classrooms. Thus, the experience with the sessions can fulfill the objective of presenting an inclusive, playful, and efficient aid in the proposed treatment available to schools. This work is ongoing and active in 2024 and 2025 with a new class. RoboDIL is being implemented in other schools, including high schools, facilitated by its low cost and user-friendly, playful interfaces.

**Acknowledgments:** To CAPES, CNPQ, and the teachers and applicators at the Municipal school.

**Conflicts of Interest:** The authors declare no conflict of interest.

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