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The Mathematical Development of Children with Down Syndrome: The Adapted Cuisenaire Material as a Learning Facilitator

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Abstract

With this study, we tried to understand how the adaptation of a manipulative material can facilitate the learning of the decomposition of natural numbers in a child with Down Syndrome. Many authors defend the use of manipulative materials to teach Mathematics to children with Down Syndrome and, also, recommend the Cuisenaire material to promote the learning of mathematical initiation concepts. However, we found that the child we study presents difficulties in terms of fine manipulation and abstraction. We promoted the adaptation of the Cuisenaire material to this student and developed an intervention program of twenty sessions, divided into three phases: manipulation of the adapted Cuisenaire; manipulation of conventional Cuisenaire and the performance of exercises. In all sessions, the child worked on the decomposition of natural numbers and the exploration of the train game. After analyzing the data collected, we found that the dimensions and textures of the adapted Cuisenaire allowed us to overcome some of the difficulties felt in terms of manipulation and abstraction and facilitated the learning of decomposing natural numbers to ten. However, the adapted Cuisenaire did not facilitate the manipulation of the conventional Cuisenaire.

Keywords: *Down Syndrome; Mathematics Learning; Mathematics Manipulative Materials; Cuisenaire; Trisomy 21*

Introduction

The scientific community has become interested in how individuals with Down Syndrome learn Mathematics. Despite the difficulties in carrying out comparative analyzes between studies, given the diversity of subjects and the evaluative measures used, some authors refer that the learning abilities of these students are greatly underestimated (Abdelahmeed, 2007; Yokoyama, 2012).

According to Silva, Brito, & Silva (2019), there is a great lack of materials to work Mathematics with students with Down Syndrome. The National Council of Teachers of Mathematics (1994) states that teachers should create their own material in order to help learn Mathematics, encouraging the use of manipulative materials in learning.

For better learning it is essential to resort to manipulative materials from Mathematics and images. The activities to be developed must explore the senses of touch and vision (Bissoto, 2005; Yokoyama, 2014; Barroso, 2018). In this context, students with Down syndrome must manipulate concrete materials at all stages of development, so that they can overcome some of the abstraction difficulties they present (Silva et al, 2019).

We proposed to adapt Cuisenaire to the characteristics of a student with Down Syndrome. According to Sampedro, Blasco, & Hernandéz (1997), these students have difficulties in terms of abstraction and fine motor skills. For these reasons, adaptation consists of increasing the dimensions of the material and covering it with different textures. Cuisenaire is a didactic material widely used in the initial teaching of Mathematics because, according to Caldeira (2009), it allows the child to learn to compose and decompose numbers.

According to Damas, Oliveira, Nunes, & Silva, (2010), the manipulative materials of Mathematics are facilitators of learning because they help students to concretize abstract concepts. Caldeira (2009), assures that Cuisenaire is a manipulative material indicated to work the decomposition of numbers. To decompose the natural numbers, the educator can dynamize the game of trains.

Fânzeres (2016), found that the activity proved to be effective in building important numerical relationships for the appropriation of concepts underlying the development of the sense of number.

These results helped us to understand the pedagogical scope of the activity that we propose to develop with this child with Down Syndrome. We tried to understand the learning of the decomposition of natural numbers, up to ten, of a child with Down Syndrome.

This theme assumes theoretical relevance and special importance in our educational practice, since we have in our class a student with Down syndrome, who reveals some difficulties in decomposing the natural numbers until ten, and in handling small objects.

The aim of this study will be to understand what extent the use of the adapted Cuisenaire facilitates the initial learning of Mathematics for a child with Down Syndrome.

In this way, we intend to assess if after the implementation of the program, the student will learn to decompose the natural numbers until ten and improve the mental calculation. We will adapt Cuisenaire in order to facilitate manipulation and potentially contribute to the development of student motivation.

Methodology

The National Council of Teachers of Mathematics (1994) encourages teachers not to limit themselves to using materials developed by third parties, but also to have the opportunity to build Mathematics. In this sense, we propose to adapt and test a manipulative material from Mathematics: Cuisenaire. The purpose of this initiative is to try to improve the initial learning of Mathematics of a student with Down Syndrome.

The general objective of the work is to understand to what extent the use of the adapted Cuisenaire facilitates the initial learning of Mathematics for a child with Down Syndrome.

In order to understand some of the phenomena that are associated with this objective, we have defined the following specific objectives:

1- Evaluate the adaptation of Cuisenaire to the characteristics of this student with Down syndrome allows him to be able to manipulate the Cuisenaire in a learning situation.

2- Analyze the use of Cuisenaire facilitates the learning of decomposing natural numbers up to ten, in this child with Down Syndrome.

3- Check if the use of the adapted Cuisenaire helps this student with Down Syndrome to learn to manipulate the conventional Cuisenaire.

4- Understand if the use of the adapted Cuisenaire by this student with Down Syndrome contributes to the development of his motivation for the initial learning of Mathematics.

Kind of Study

The present study is case study based on the qualitative research paradigma, It is a cross-sectional study that intends to be carried out in a short period of time considering a particular reality. The qualitative method will be used in the context of action research.

Subject, Materials and Means

The subject selected for the study has the diagnosis of Down Syndrome and attends the second year of schooling. This child is male and eight years old. In this case study we will study only one subject. The selection of the subject under study was made by convenience.

In addition to the difficulties shown in the composition and decomposition of numbers, it is important to emphasize that this child has limitations in the field of fine motor skills. Due to these complications, the student cannot handle this teaching material correctly. The white pieces (units) of Cuisenaire are one cubic centimeter and, therefore, the student has difficulty manipulating and grouping them.

Sampedro et al (1997), explain that the fact that children with Down Syndrome have some morphological peculiarities (low implantation of the thumb, short fingers and absence of the last phalanx of the little finger) and muscular hypotomy considerably impairs the way they handle the objects and work tools. It is necessary to teach how to manipulate objects and structure activities that favor the sense of sight and touch. In this domain, Troncoso and Cerro (2004) state that pinch grip can be replaced by lateral grip. For this reason we decided to increase the dimensions of the Cuisenaire pieces. The white piece (unit) now has eight cubic centimeters in volume. This modification is intended to help the student manipulate the material.

For Troncoso and Cerro (2004), it is essential to teach children with Down Syndrome to manipulate materials and objects with various dimensions and textures, in order to help them perform more complex tasks. For this reason, the other change produced in the teaching material is the delimitation of the grouping of units on the faces of each piece. By delimiting the sum of units, with different textures, the student can visualize and feel the area that each unit occupies in a given piece. This adaptation aims to make it easier for the child to identify the number of units contained in each piece. The visual support (graphic delimitation) seeks to facilitate the counting of units. Sensory stimulation is intended to help the student count the number of times each piece changes texture (thus identifying the value of each piece). This modification seeks to adjust the manipulative material to the characteristics of this child.

The adapted Cuisenaire is used in the same way and explored with the same technical and didactic procedures. In short, the changes produced in this teaching material are intended to help this student to manipulate and explore it effectively. Each white piece (unit) now has eight cubic centimeters. Different textures were alternately glued to the various faces of each piece. One of the textures is smooth and the other is rough. The intention of this modification is to help the student to develop calculation and counting in a learning context.

To carry out the study, we will build an intervention program with the planning of twenty sessions. There will be three sessions per week over a period of seven weeks. The sessions will be facilitated by the researchers.

In order to help the subject studied to overcome the difficulties, we will develop a training program of 20 sessions, divided into three distinct phases: in the 1st phase, the student will manipulate the adapted material and play the train game (decomposition of numbers); in the 2nd he will manipulate the conventional Cuisenaire and try to carry out the same activity and in the 3rd he will try to decompose the natural numbers up to ten based on Cuisenaire images.

To collect data, we will prepare an observation grid that will allow us to structure the aspects to be observed. The observation will be focused, since we only intend to collect data related to the interaction between the student with Down Syndrome and the manipulative materials of Mathematics at planned moments. Observation will be participatory so that we can perceive the phenomenon directly. The observation grids will be filled in by the researcher.

Results

Description of Results

We begin by presenting the synthesis of observations from the sessions carried out with the student with Down Syndrome. As we can see in TABLE 1, to better understand student performance, categories were created that mirror the domains observed in the observation grids.

Table 1 - summary of observation of the sessions

Categories	Subcategories	Examples	Frequency
Be alert	Manifests attention behaviors.	"The student listened to the directions carefully." (S2)	12
	Sometimes manifests attention behaviors.	"The student was inattentive." (S4)	3
Be happy	Expresses emotional satisfaction. happiness and enthusiasm." (S2)	"The student showed happiness and enthusiasm." (S2)	44
	Expresses emotional problems during part of the session.	"The student was a little disappointed (…)" (S17)	4
Be motivated	Express collaboration during the session.	"The student seems to be very motivated." (S3)	20
	He sometimes manifests disinterested behavior.	"The student reacted with some opposition to the proposed task." (S8)	2
Handling the adapted Cuisenaire	Easily manipulates.	"The student shows ease in handling the adapted Cuisenaire." (S2)	7
	Handles with difficulty.	-	0
Conventional Cuisenaire handling	Easily manipulates.	-	0
	Handles with difficulty.	"The student shows great difficulties in handling the pieces." (S8)	9

Categories	Subcategories	Examples	Frequency
Mental calculation	Performs mental calculation operations with ease.	"The student begins to show some autonomy and agility in mental calculation." (S19)	9
	Performs mental calculation operations with some ease.	"It seems that he developed some automatisms in terms of mental calculation (…)" (S11)	9
	Performs mental calculation operations with difficulty.	"He demonstrates difficulties at the level of mental calculation." (S2)	13
Number decomposition	Decomposes easily.	"Its evolution in the domain of number decomposition is evident." (S19)	5
	Decomposes with some ease.	"The student can perform more complex decompositions (more than two pieces)." (S11)	13
	Decomposes with difficulty.	"It reveals some difficulties in terms of mental calculation and decomposition of numbers." (S4)	5
Motor/emotional agitation	Motor/emotional agitation	"The student shows some anxiety." (S3)	7

One of the categories determined is related to student motivation. It is important that the subcategory, "The student manifests collaboration during the session", has a frequency of 29 occurrences, which shows that the student reacted very positively to this intervention program. During the implementation of the program, the student manifested disinterested behaviors on two occasions. It appears that the implementation of this program helped to motivate the student to learn how to decompose natural numbers up to ten.

Another category is related to the happiness shown by the student throughout the implementation of the program, the subcategory, "Manifests emotional satisfaction", has a frequency of 44 occurrences. Only on four occasions did the student show emotional problems during part of a session. Comparing the above data, it can be seen that the student felt clearly happy with the implementation of the program.

One of the categories listed relates to the observation of student attention throughout the implementation of the program. The student manifested attention behaviors on 12 occasions. The subcategory, "Sometimes manifests attention behaviors", had a frequency of three occurrences. Based on these, we can observe that the activities implemented aroused the attention and interest of the student.

Regarding the category that is related to the manipulation of the adapted Cuisenaire, it is important to mention that in the first seven sessions of the program the student worked with this material. In all these sessions the student demonstrated ease in handling the adapted Cuisenaire.

In the second phase of the program implementation, the student worked with conventional Cuisenaire. In seven sessions, the student demonstrated manipulation difficulties on nine occasions. In all

the sessions carried out with the adapted Cuisenaire, the student found it easy to manipulate the material and in all the sessions carried out with the conventional Cuisenaire, he felt manipulation difficulties.

Another specific category concerns the development of the student's mental calculation. To better understand the evolution of the student in this domain, three subcategories were determined. The subcategory “Performs mental calculation operations with difficulty.” has a frequency of 13 occurrences. These occurrences manifested themselves, essentially, in the first sessions of the implemented program. As the sessions went on, the student made progress and managed to perform mental calculation operations with some ease in nine moments. The subcategory “Performs mental calculation operations with ease.” has a frequency of nine occurrences. These data reflect the student's evolution in the field of mental calculation.

It is important to mention that the student had a very positive evolution in terms of the ability to decompose natural numbers up to ten. Three subcategories were defined that illustrate this evolution well. The subcategory “Decomposes with difficulty.” has a frequency of five occurrences. These occurrences manifested themselves in the initial phase of program implementation. The subcategory “Decomposes with some ease.” has a frequency of 13 occurrences. In the last sessions, the student can perform the number decomposition with “easiness”. This subcategory has a frequency of five occurrences. Based on these data, we can verify that the implemented program helped the student to develop his ability to decompose natural numbers up to ten.

It is essential to emphasize that during the implementation of the program the student manifested some motor/emotional agitation on seven occasions.

In TABLE 2 we can see the student's self-assessment record. At the end of each session, the student filled in a self-assessment registration grid, where he classifies his performance, surrounding a “smile”. This self-assessment record grid is intended to obtain the student's opinions regarding their performance. The student needed some guidance and help to complete each self-assessment grid.

TABLE 2. Assessment of the final self-assessment record of the activities developed by the student

Items to be assessed	Student self-assessment		
1- The material handling was…	difficult . 7	easy. 0	very easy. 7
2-The exercises performed were…	difficult. 2	easy . 12	very easy. 6
3-To complete the activity I needed…	a lot of help. 4	help. 3	no help. 13
4-When executing the activity…	I didn't like the exercises. 0	I liked the exercises. 0	I really enjoyed the exercises.20

When looking at the final self-assessment table, we found that the student classified handling the material as difficult on seven occasions and as very easy on seven occasions. It is important to emphasize that he never classified material handling as easy. Now, these data allow us to verify that in the seven sessions in which he manipulated the adapted Cuisenaire, he felt very easy. On the other hand, in the

seven sessions in which he operated with the conventional Cuisenaire he experienced difficulties in terms of manipulation. It appears, therefore, that the student manipulates the adapted Cuisenaire very easily and the conventional Cuisenaire with difficulty.

Another aspect that deserves to be highlighted is that the student classifies the exercises performed in 12 sessions as "easy" and the exercises performed in two sessions as "difficult". In the last sessions of the program, the student classifies the exercises as "very easy" (in six sessions). These data prove that the exercises proposed throughout the program were adequate to the student's cognitive level.

However, he recognizes that he needed "a lot of help" in four sessions and "help" in another three sessions. It is important to highlight that he considered that he did not need help in 13 sessions. These data demonstrate that the student progressively acquired some autonomy in terms of performing tasks. Therefore, he considers that in seven sessions he needed support and in the remaining sessions he was able to operate autonomously.

It is imperative to emphasize that the student assumes that he really enjoyed the exercises proposed in the 20 sessions. This information allows us to verify that the student was highly motivated throughout the implementation of the program.

Discussion of Results

The first objetive of this study was evaluate the adaptation of Cuisenaire to the characteristics of this student with Down syndrome allows him to be able to manipulate the Cuisenaire in a learning situation. According to the data collected, we found that the student is easier to manipulate the adapted Cuisenaire and has some difficulties in manipulating the conventional Cuisenaire. In the seven sessions in which he manipulated the adapted Cuisenaire, it was possible to observe a great ease in manipulation. In the context of self-assessment, the student considered that handling the material was very easy. The National Council of Teachers of Mathematics (1994) maintains that manipulative materials must be permanently analyzed and adjusted to the needs of students. It can, therefore, be said that the adaptation of the Cuisenaire allowed the student to manipulate it more easily.

The second objetive was understand if the use of the adapted Cuisenaire facilitates the learning of decomposing natural numbers up to ten by this child with Down Syndrome. By observing the summary grid of the sessions, we can see that the student evolved favorably over the 20 sessions. In the last five sessions the student performs decompositions with ease. When comparing the pre-test and the post-test, we found that the student made great progress in terms of decomposing numbers up to ten. In the final self-assessment register grid, the student considers that most of the exercises performed were easy or very easy.

Yokoyama (2014) and Barroso et al (2018), ensure that the use of manipulative materials and games help students with Down Syndrome to learn mathematical concepts. These authors guarantee that it is essential to use multisensory materials to teach mathematical concepts to students with Down syndrome. According to Caldeira (2009), the Cuisenaire material helps students acquire the notion of number and explore the relationships between numbers. This author mentions that the "trains game" allows to work the decomposition of numbers in a playful way. Coelho et al (2010), guarantee that the use of Cuisenaire allows the child to understand the natural numbers from one to ten and learn to establish the correspondence between quantities and numerical values. According to the results obtained and with the knowledge of the aforementioned authors, we found that the use of Cuisenaire facilitated the learning of decomposing natural numbers to ten by this child with Down Syndrome.

The third objetive was to understand if use of the adapted Cuisenaire helps the student to manipulate the conventional Cuisenaire. We verified that he found it difficult to manipulate the

conventional Cuisenaire in all the sessions in which it was explored. In the final self-assessment registration grid, the student indicated that handling the material was difficult in all the sessions in which the conventional Cuisenaire was used. The student stated that the manipulation was very easy in the sessions in which the adapted Cuisenaire was used.

Troncoso and Cerro (2004), guarantee that children with Down Syndrome have difficulties in fine manipulation due to the anatomy of the hand. Block (1991, cited by Morato, 1995), states that children with Down Syndrome have difficulties in terms of global and fine motor skills. Based on the data collected, we found that the use of the adapted Cuisenaire did not help this student with Down Syndrome to learn to manipulate the conventional Cuisenaire.

The fourth objetive was to know if the use of Cuisenaire contributes to the development of this student's motivation for the initial learning of Mathematics. Based on the observation of the data present in the summary grid of the sessions, we can see that the use of Cuisenaire contributed to the development of student motivation. In the final self-assessment register grid, the student says that he really enjoyed the twenty sessions.

According to Silva (2016), manipulative materials promote student motivation. Damas et al (2010) corroborate this idea as they claim that manipulative materials help to involve the student in the learning process and arouse great enthusiasm. It is important to mention that according to Sampedro (1997), children with Down Syndrome have a special taste for games. We verified, therefore, that the use of Cuisenaire contributed to the development of the motivation for the initial learning of Mathematics of this student with Down Syndrome.

The central objetive of this study was to understand whether the use of the adapted Cuisenaire facilitates the initial learning of mathematics for this child with Down Syndrome. We can consider that this child can manipulate the adapted Cuisenaire with ease. The use of it contributes to the improvement of the ability to decompose natural numbers up to the tenth. However, the manipulation of the adapted Cuisenaire did not contribute to the better manipulation of the conventional Cuisenaire. It is important to emphasize that the use of the adapted Cuisenaire helped to motivate this student for the initial learning of Mathematics.

In the perspective of Silva (2019), students with Down Syndrome should use manipulative materials at all stages of development in order to overcome some of their abstraction difficulties. Abreu, Santos, & Rodrigues (2018), ensure that Cuisenaire allows for various activities and helps the child to become more autonomous. Goutard (2011, cited by Vergoni, 2018) also guarantees that Cuisenaire helps children learn the bases of arithmetic and elementary algebra.

So, we can consider that the adapted Cuisenaire facilitated the initial learning of Mathematics for this child with Down Syndrome.

Conclusions

This research work was a great challenge for those who participated in it. The scientific community still seeks to build knowledge about how students with Down Syndrome learn mathematical concepts. Whit this in mind, this project was based on the adaptation of Cuisenaire to the characteristics of a child with Down Syndrome, focusing their learning on decomposing natural numbers to the ten.

During the investigation we found that the student showed a greater interest in handling the adapted Cuisenaire than the conventional Cuisenaire. We can conclude that the use of the adapted Cuisenaire facilitates the initial learning of Mathematics for a child with Down Syndrome.

We recommend that future studies explore the potential of Cuisenaire with more children with Down Syndrome. It is important to emphasize that the conclusions of this study cannot be generalized due to the fact that it is a case study.

Cuisenaire can explore arithmetic operations, symmetries, perimeters, areas, volumes and other mathematical concepts.

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