Abstract

Technological progress is a feature of everyday life in society, and school, as an integral part of it, must follow this development with changes in educational practice. School must work towards inclusion and equity of learning for all pupils. In this context, educational technologies appear to be very relevant tools regarding their potential for improving the education of children with learning difficulties. One of these educational technologies is the Scratch platform. The main objective of this study was to understand how the use of the Scratch software can contribute to the learning of mathematical content, specifically the affine function, by two children with learning difficulties. The research consisted of the application of a pre-test, followed by a two-session intervention and concluded with the application of the post-test. The mixed methodology focused on the quantitative analysis of pre- and post-test results and on the qualitative analysis of elements of the students' records, of the elements that they produced in the computer and of the researcher's field notes. The results suggest that the intervention had a significant impact on the overall performance of the two students, although with different relevance. The results also indicate that the work developed in Scratch enabled the students to have a better understanding of concepts, rules and symbols of mathematics. Despite the obvious limitations of this study and the impossibility of generalizing results, the conclusions provide arguments in favour of confirming Scratch as a valid and capable alternative for the promotion of learning, mathematical learning and the development of children with learning difficulties.

Keywords: Scratch, learning disabilities, technology, mathematics.

1 INTRODUCTION

Technological progress is a feature of everyday life in society, and school, as an integral part of it, must follow this development with changes in educational practice. There are also important changes in mathematics, particularly in the understanding of what mathematics is and how to teach mathematics [1]. It is more than concepts and skills. In addition to academic and social skills, basic mathematical skills are needed for use in everyday life. Mathematics plays a facilitating role and, therefore, individuals with special needs need to acquire mathematical skills [1]. According to the same author, students can acquire these skills when they are confronted with appropriate educational environments, based on their specific characteristics and needs, and in a school for all, for all and with all, differences should be opportunities to promote the integral development of each and every one [2].

The Portuguese public school has recently developed an effort for the inclusion and equity of learning for all students. Decree-Law n. º 54/2018 of 6 July 2008 establishes the principles and standards that ensure inclusion as a process that aims to respond to the diversity of the needs and potential of each and every student. The guiding principles are, among others, universal educability (the assumption that all children and students have the capacity for learning and educational development), equity (all students have access to the necessary support in order to achieve their learning and development potential), inclusion (full and effective access and participation to the same educational contexts) and personalisation (learner-centred educational planning, so that measures are decided on a case-by-case basis according to their needs, potential, interests and preferences, through a multi-level approach).

In this context, educational technologies emerge as very relevant tools to support inclusion given the enormous potential they have in improving the education of children with learning difficulties [2]. Still
according to the same researcher, it is necessary that the teachers who work with these children follow the advancement of new technologies, considering them as an indispensable educational resource in an increasingly digital society. Digital materials are tools that facilitate improvements in students' functionalities and facilitate the reduction of their disabilities as they prevent, compensate, alleviate or neutralize functional limitations, and contribute to improvements in communication, manipulation, guidance, learning, autonomy, interpersonal relationships and social participation [2]. The integration of technology in the classroom context for students with special educational needs is seen by teachers and educators as a factor of positive impact on access to the curriculum, academic progress, emotional and social development, control and reward of behaviour and, when considering their interests, motivation [3].

Recent research points to the value and importance of the integration of technology as a support to the teaching and learning of students with special needs (e.g. [1], [2], [3], [4], [5], [6]). By educational technology we mean any tool, resource or integrated educational practice that promotes learning or improves learning outcomes [7]. Therefore, the use of interactive whiteboards and presentation tools by teachers, the use of computers or tablets by students and the use of programs for the promotion and management of learning are included [8].

For example, [4] investigated how the introduction of a physical toolkit could support the learning of computing concepts for students with special education needs in the classroom context. They concluded that physical interfaces are very promising in classrooms, especially when the task design and materials allow self-regulated learning with the appropriate support of teachers. These types of tasks contribute to leveraging the ability to collaborate and engage in the content dealt with alongside understanding and sense of personal fulfilment.

Teachers are responsible for the integration of educational technologies [1] and teachers who deal with students with learning difficulties have, in general, a positive attitude about their use and this position has an impact on the actual use of technology [8]. According to the same author, teachers should experience practical activities that focus on the use of the tool and on the abilities to influence students' learning.

One of the prominent educational technologies is Scratch. Developed by the Lifelong Kindergarten Group at MIT (Massachusetts Institute of Technology), it is a programming software that allows the creation of animated projects, in a simple and intuitive way. The programming is carried out using blocks so that, in addition to being empirical for students, it does not lack specific knowledge in a programming language, fully highlighting the focus on the algorithm.

In [2] we find a curricular experience with Scratch. The objective of the study was to understand the benefits of using this software as a tool to develop materials for a child with special educational needs, focused on content in Portuguese and Mathematics. The study included six sessions through project work in order to stimulate the cognitive level of the student involved, improving their perception of the contents. Despite being a preliminary study, the researchers concluded that there were impacts in terms of performance, more significant in Portuguese, and that the student had greater difficulties in solving mathematical problems with daily tasks. Finally, they mentioned that the use of Scratch to promote specific curricular competences in professional contexts is a beneficial and valid alternative in the development of children with special educational needs.

Usually associated with this type of educational software is the development of computational thinking [9]. Defined as the thought processes involved in formulating problems so that solutions can be represented as algorithms [10] or simply as an algorithmic approach to solving any kind of problem, computational thinking is a combination of mathematical thinking and engineering thinking, a freshly thought product that helps us to solve problems, to manage everyday behaviours and communication and interaction skills with our peers, and a basic ability in everyday life [11]. Indispensable for all students and not only for students in the field of computing, all children should have the opportunity to develop the analytical capacity of computational thinking [11]. Once again, it is up to educators and teachers to promote their learning.

2 METHODOLOGY

The main objective of the study was to understand how the use of Scratch software can contribute to the learning of mathematical contents related to the linear function by two children with learning difficulties.
The investigation consisted of the application of a pre-test, followed by a two-session intervention and concluded with the application of the post-test.

The first intervention session lasted 50 minutes and was designed to introduce students to Scratch and give them the opportunity to explore the software. After examining the commands, the teacher built a programme together with the students to obtain the sum of two values requested from the users. The teacher later challenged the students to programme for other operations. In addition to the familiarisation with the software, this action was intended to introduce the concept of variable. In the second session of the intervention, lasting 100 minutes, the students collaboratively performed the proposed task on the linear function.

The mixed research method was chosen for this research. A quantitative analysis of the pre and post-test results was carried out, the elements recorded by the students and the elements they produced in the Scratch programme were analysed qualitatively.

2.1 Participants

Two students from the same class in the 10th grade of a Portuguese public school participated in the study. The students have a school path without retentions but benefit from a specific individual curriculum given the diagnosis of mild cognitive impairment.

The condition of mild cognitive impairment is characterized by difficulty and slowness in reading, understanding texts and statements, writing and mathematics, communication and, sometimes, compliance with established norms. Students are autonomous and have a good relationship with peers and teachers but have difficulties in dealing with error and failure due to low self-esteem.

2.2 Instruments

The work consisted of three moments: application of the pre-test on the linear function, intervention with a task for development with Scratch and application of the post-test. The pre-test and post-test are the same and in both cases the use of the calculator was authorized in question 3 (of 3 items).

The pre-test and post-test consisted of three questions subdivided into 10 items. In the first question they were asked to determine the images of some objects (Fig.1) and the objects corresponding to other images. Different forms of presentation of this type of question and the mathematical symbology of functions were also explored.

1. Consider the function \( f \) defined by \( f(x) = 3x + 1 \).

   1.1 Complete the following table:

<table>
<thead>
<tr>
<th>object ( x )</th>
<th>1</th>
<th>0</th>
<th>−2</th>
</tr>
</thead>
<tbody>
<tr>
<td>image ( f(x) )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   *Figure 1: Pre-test and post-test item 1.1 (translated from the original in Portuguese).*

The second question was to assess knowledge of the priority of operations. Finally, the third question (Fig. 2) deals with a small model of a real situation, of gradual difficulty, which culminates in the proposal of an expression that relates the two variables involved.

Each item was assigned a rating from 0 to 10% according to the specific classification criteria established.

3. Joana went shopping and returned home by taxi. The flat rate for taxi ride is 3 euros and every kilometre of the trip costs 0.50 euros.

3.1 What was the cost of the trip if Joana travelled 10 km?

   *Figure 2: Beginning of question 3 of the pre-test and post-test (translated from the original in Portuguese).*
The task outlined for the intervention with Scratch followed a very similar pattern to the pre-test, consisting of three subtasks that suggested the construction of programmes (Figs. 3 and 4) to obtain answers to the following items.

<table>
<thead>
<tr>
<th>Item</th>
<th>1.1 Using [Scratch] builds a program that allows you to calculate the image (y or f(x)) of any object (x).</th>
</tr>
</thead>
</table>

**Figure 3: Task item 1.1 (translated from the original in Portuguese).**

<table>
<thead>
<tr>
<th>Item</th>
<th>1.4 Using [Scratch] builds a program that allows you to calculate the object (x) from the image (y or f(x)).</th>
</tr>
</thead>
</table>

**Figure 4: Task item 1.4 (translated from the original in Portuguese).**

Question 3 of the task was a realistic problem of design and resolution similar to the one used in the pre-test and it was suggested that students created a programme that would allow them to calculate one variable (cost in euro) from another (time in hours) (Fig. 5).

<table>
<thead>
<tr>
<th>Item</th>
<th>3.1 The technician went to Mr. Pinto's house and took two hours to fix the washing machine. How much did Mr. Pinto pay the technician?</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>Builds a [Scratch] programme that allows you to calculate the cost, in euros, of repair depending on time, in hours.</td>
</tr>
</tbody>
</table>

**Figure 5: Items 3.1 and 3.2 of question 3 (translated from the original in Portuguese).**

### 3 RESULTS

The results obtained are analysed in three different but complementary aspects: the quantitative results of the pre-test and post-test; the results from the qualitative analysis of the elements produced by the students; and the qualitative analysis of elements of the pre-test and post-test.

#### 3.1 Pre-test and post-test results

When comparing the pre and post-test results, tables 1 and 2, indicate an overall improvement in the performance of the two students, with a higher score for Student 1, who recorded a further 45.5% in the final grade. Pupil 2 improved his score by 13%.

<table>
<thead>
<tr>
<th>Item</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>2.1</th>
<th>2.2</th>
<th>3.1</th>
<th>3.2</th>
<th>3.3</th>
<th>3.4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>3.5%</td>
<td>0%</td>
<td>0%</td>
<td>n.r.</td>
<td>n.r.</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>n.r.</td>
<td>n.r.</td>
<td>28.5%</td>
</tr>
<tr>
<td>Post-test</td>
<td>10%</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>n.r.</td>
<td>n.r.</td>
<td>74%</td>
<td></td>
</tr>
</tbody>
</table>

In the pre-test, Student 1 only showed a positive performance in the resolution of two items of question 3 that dealt with a realistic situation but revealed difficulties in the resolution of the other items that did not deal with mathematical applications. Pupil 1 was the most active student during the performance of the intervention task with Scratch and, although there was collaboration between the

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students and occasional sharing of ideas, he was responsible for the execution of most of the programmes. In the post-test, Student 1 correctly answered the image calculation items of some objects, presented in various forms and through the specific symbolism of the functions, significantly improved the results in question 2, where the knowledge about the priorities of the operations was assessed and maintained the performance in question 3, which was representative of an application of mathematics.

Table 2. Pre- and post-test results for Student 2.

<table>
<thead>
<tr>
<th>Item</th>
<th>1.1</th>
<th>1.2</th>
<th>1.3</th>
<th>1.4</th>
<th>2.1</th>
<th>2.2</th>
<th>3.1</th>
<th>3.2</th>
<th>3.3</th>
<th>3.4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>8%</td>
<td>10%</td>
<td>n.r.</td>
<td>n.r.</td>
<td>2%</td>
<td>2%</td>
<td>10%</td>
<td>10%</td>
<td>n.r.</td>
<td>0%</td>
<td>42%</td>
</tr>
<tr>
<td>Pos-test</td>
<td>10%</td>
<td>10%</td>
<td>n.r.</td>
<td>n.r.</td>
<td>10%</td>
<td>5%</td>
<td>10%</td>
<td>10%</td>
<td>0%</td>
<td>n.r.</td>
<td>55%</td>
</tr>
</tbody>
</table>

In the pre-test Student 2 revealed a positive performance in determining the object images (1.1 and 1.2) and the two items in question 3 that dealt with a realistic situation. During the intervention, this student, despite collaborating with the colleague in the form of suggestions and small corrections, was more passive and expectant, and only built one of the programmes requested after the colleague insisted to do so. The post-test results revealed a similar performance in the items in which he had already obtained positive performance and an improvement in items 2.1 and 2.2 that required attention to the priority of operations in the calculation of images.

Comparatively, Student 2 performed better than Student 1 in the pre-test, but in the post-test it was lower and the evolution, although significant, was also lower. These results seem to be related to the role that each student played during the intervention. Student 1 led the task and was responsible for building the Scratch programmes, while Student 2 was more passive and interacted less with the software.

3.2 Intervention with Scratch

For the purpose of this study it is important to understand how the use of Scratch contributed to the development of mathematical understanding. Thus, the analysis of the events of this intervention and the elements produced by the two students become relevant.

The previous knowledge of the software menus and the creation of variables resulting from the introductory and exploratory session were decisive for the beginning of the students' work. The teacher proposed to review these aspects together with the students, but the suggestion was immediately rejected. The students mentioned that they still remembered and, if necessary, requested support. After making sure that the students read the first question and understood what was intended, the teacher allowed them to work independently, often approaching to verify the development of the work.

The students understood that the "kitten" had to greet people before requesting the value for the object. They then discussed what they had to do first and concluded that they should ask for a value "as they had done in the other lesson to do the math". They created the "object" and "image" variables and integrated them correctly into the programme but had some difficulties in building the block corresponding to the image calculation formula and requested the support of the teacher. The teacher verified that they knew the order of the operations and used the "object" variable correctly but could not integrate the blocks in each other as they intended. They built the programme reproduced in Fig. 6 that allowed them to effectively answer the following two questions about calculating images from indicated objects. The figure shows the answer to the "f(-5)" calculation.

In addition to the already mentioned mathematical elements, note the chosen sequence of commands, that is, the algorithm converted into a correct and functional programme, and the discussion that preceded it. Although in a simple and tenuous way, the students worked on their computational thinking skills. In addition, the students showed a lot of attention and their involvement was very significant, showing a willingness to solve the questions asked in the task well and quickly.
In item 1.4 of the task they were asked to build a programme to determine the object from the image. The students asked the teacher for help because “they did not understand what they were supposed to do”. Explained what was intended, Student 1 said that “it is the opposite, we have to exchange the objects for the images and the images for the objects”. In the programme of Fig. 7 they changed the position variables and asked for support again. The teacher then asked them to test the programme with a previous result such as, for example, the -7 image corresponding to the -5 object. They immediately found that it was wrong, and Student 2 suggested that the error was in the “green block” formula. Then the teacher took the opportunity to analyse the order of the operations to be performed in the calculation of images from objects and explained that to determine objects from the images had to perform the reverse path, that is, the operations would also be the inverse and with reverse priority. After the explanation the students, again with some difficulties in the assembly of the formula block, built the programme of Fig. 7. In the same it is possible to see the result of the calculation of object 9.5 from image 11 which was one of the questions that followed for application of the programme.

The resolution of these items allowed us to address the inverse operations and deepen the concept of object and image. By testing the programme, searching for errors and rethinking it as an "inverse path" of the previous one, it allowed, once again, to work at the level of computational thinking.

The discussion and analysis of the previous programme were enough for students to build a programme capable of calculating the images in the function defined by \( f(x)=2(x+3) \). To make sure Student 2 also asked the teacher if “first was the parenthesis”.

The programme, reproduced in Fig. 8, shows the care students took in first obtaining the sum of the object with 3 and then only the product of the sum by 2, that is, the concern with the priority of operations.
In question 3, which was intended to be an example of a realistic situation, the students immediately created the variables money and time and moved on to the adaptation of the previous programme. After they finished, they asked the teacher to look at the programme. The teacher found that they had an incorrect “hour” worth 16 euros and a fixed travel value of 14 euros. To explain the error, the teacher asked them to test it with the values of item 3.1 that they had already determined with the calculator. When they concluded that something was wrong, they went back to the statement, but only with the help of the teacher did they detect the error. They immediately made the necessary changes and presented the programme of Fig. 9.

This episode of autonomous creation of new variables suggests that students have understood the concept of variable and feel confident in its manipulation. They also correctly constructed the formula corresponding to the calculation of the cost of repair, although they changed the values.

Once again, the students worked at the level of computational thinking. They adapted the programme, tested it, detected the errors and corrected it.

Finally, students were asked to write an expression relating the cost in euros and time in hours. The pupils read but found it too difficult and did not even outline an attempt at an answer. This is an exercise that requires some abstract reasoning, in which the students have more difficulties. The failure to respond may also be due to a lack of understanding of what was requested or to the progress of the lesson that was coming to an end.

### 3.3 Analysis of pre-test and post-test elements

In addition to the quantitative results of the pre-tests and post-tests and their comparison, we highlight here the elements present in the answers that may help to understand the impact that the intervention had on the students’ mathematical performance.

In items 1.1 and 1.2 of the pre-test Student 1 answered incorrectly showing difficulties in calculating images from the objects. The answer suggests that he did not master the concept of variable and that
the algebraic expression was strange to him, a misunderstood element. In the same items, in the post-
test, the student had an exemplary performance (Fig.10) and the answer suggests the adaptation of
the reasoning performed in the construction of the programme in Scratch.

In Student 1’s answers to item 1.3 (Fig. 11), to determine the images from the objects, the influences
of the construction of the programme in Scratch, the discussion that preceded it about the “inverse
path” and the inverse operations, and the reasoning performed with computational thought
characteristics seem evident in the post-test. In the pre-test he did not answer.

Also, in question 2 Student 1 seems to use skills he or she has acquired in the intervention performed.
The separation and sequencing of operations to obtain the value of the image configure the
application of small algorithms, that is, computational thinking (Fig.12). Student 2 opted for a different
process (Fig 13).

Although the two students’ responses had an error in item 2.2, their performance improved
significantly in this question.
4 CONCLUSIONS

The main objective of this study was to understand how the use of Scratch software can contribute to the learning of mathematical contents related to the linear function by two children with learning difficulties.

Pre and post-test results suggest that the intervention designed with Scratch had a significant impact on the overall performance of the two students, although with different relevance. The evolution of performance seems to be associated with the development and application of reasoning and thoughts with computational thinking characteristics. The analysis of the elements collected during the intervention and in the tests applied also indicate that Scratch enabled students to have a better understanding of concepts, rules and symbols of mathematics. Students were involved throughout the process and had very assertive behavioural reactions to the proposed intervention. They often question when they return to work with Scratch.

Notwithstanding the obvious limitations of this study and the impossibility of generalizing results, the conclusions provide arguments to confirm that Scratch is a capable and valid alternative to the promotion of learning, mathematical learning and development of children with learning difficulties.

REFERENCES


