A Prototype Electronic Toy for the Development of Mathematical Logical Reasoning in Children from Five to Seven Years Old Using Python

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Abstract The technological advance and the great importance that it represents when using Information and Communication Technologies (ICT) as a tool in the educational process allows us to search for strategies to take advantage of the benefits that can be achieved by involving these advances in initial education, in this sense, the development of an electronic device that uses different elements such as readers and labels with Radio Frequency Identification (RF-ID) technology, a sensor to identify colors, a Raspberry Pi minicomputer, LCD screen, among others, are presented, together with the development of strategies and didactics that allow the device made as an electronic toy to an element to help stimulate logical thinking in children between the ages of five and seven, given the already showed importance that early strengthening of abilities such as identifying, relating and operate different types of situations that allow people to function in society in real situations.

Keywords RF-ID · Sensor · Logical · Technology · Children
1 Introduction

The advance that technology and its use as a learning support tool are clear in the development of applications and devices available today. This significant advance has generated important changes in the learning process. This intimate relationship developed between learning and ICT is evidenced, for example, in the way children identify with video games, perhaps for the quality of the graphic environment, the multimedia characteristics, or other factors that make these environments capture their attention; that is why the cognitive area has to be stimulated correctly using all kinds of tools, including technological ones [19].

The main objective of this project is the development of an electronic device that has the characteristics of a toy. This device can be used as a teaching tool that based on some basic concepts of mathematics, presents exercises to the user so that through play reason the solution to the different approaches, for this different objects are used that when combined with some electronic components such as RF-ID readers and tags, color sensors among others allow generating interactivity.

The use of mathematics as part of this project arises from the importance that it has shown for the formation of people because they streamline reasoning and merge the teaching of the other disciplines. In this way, individuals make deductions during the different activities carried out in society when they apply to real situations. The development of logical thinking requires the design of activities where aspects such as the properties of objects, the organization of information, the relationships, diagrams, charts, and diagrams are all considered focused on creating content to perform in activities that for children should be simple, interesting and above all entertaining [2, 4, 14].

The technological means used to develop tools that help in learning must allow the communication of its contents to be effective, and the interaction with the user must be simple to facilitate learning, in terms of the technology used for learning, for children as Poole mentions it should allow the stimulation of sight, hearing, touch, and mind by combining multimedia [5, 16].

Regardless of the technology used, as mentioned by Salguero [20], the most important thing should be to play, due to the importance it has at the educational level in children, it allows them to discover the qualities of objects, make comparisons, build knowledge, and above all, it helps children to relate to others.

In this same sense, Rodríguez mentions that the game, being a way of interacting with reality, is typical of childhood, is universal, and leaves a mark on people because it leaves a psychological framework that gives meaning and evolves with age by reflecting the moments when a relationship is generated between the world and the individual [12].

This project aims to develop a tool that allows children to improve some skills through the use of critical thinking, since as Rivas mentions [18], in this way, it contributes to the formation of the habit of using this kind of thinking in all areas of life without leaving aside creativity and observation.
2 Background Literature

Taking into account that the current generation has developed in a world where technology is present, in almost all human activity, learning when technology seeks to be of great value must allow students to test their skills by making interaction more visual, personalized, and above all, focused on solving a problem [13].

There are several studies focused on highlighting the importance of play in child development as highlighted by Baste [9], who analyzes the experience of several researchers who agree that the selection of a suitable game generate great benefits, especially when it takes the advantages attributed to the game, and those associated with the serious work, in this sense, a game that can become a satisfying, relaxing activity and capable of producing fun, may also require effort, use of memory, among other characteristics that allow the generation of learning that can be conceptual, procedural, and of attitudes.

In this sense, the work carried out by Hofer [11], who highlights the importance of ICT together with logical-mathematical development for children to learn mathematics, for which she developed, an interactive game using PowerPoint, this game, she exposes shapes, colors, and sizes to apply the learning of logical-mathematical, which is very important when it is incorporated from an early age. In this way, the development of the training, the application, and the instrumentation functions make children understand and know their environment.

Also, it is possible to highlight the work of Hidalgo [10], who mentions the importance of logical-mathematical to express the result of reasoning in a clear and organized way. To do this, he presents the introduction to logic, through the approach of a system of strategies, taking into account the importance of mathematical language in the different modes of action that a person can have, hence the importance of linking logical-mathematical intelligence with the different abilities and strengths that can be detected, and worked with children to enhance the intelligence associated with, for example, problem-solving, pattern detection, understanding the cause and effect of an event, the ability to abstract, and even critical thinking.

Regarding technological applications that serve as a tool for the stimulation of mathematical thinking, the project presented by Vázquez [1] also stands out, who developed a video game that can be used by preschool children to take advantage of the advantages that they can provide physical activity and a video game in between when they support the stimulation of mathematical thinking through mini-games in a classroom.

In this sense, the work of Carrera [6] also stands out, who implemented educational video games that allow the learning of mathematics through a qualitative approach, obtaining as a result that it is possible to capture and sustain the student’s attention with this type of digital resources. In this case, applied video games are of great help because children are interested in playing while they are learning due to the characteristics of this type of software that allows them to capture the student’s attention.
There is also literature on works focused on a certain group of students, such as that of Tangarife [7], who in his work presents an application designed to facilitate the teaching of basic operations of Mathematics to people with Down’s Syndrome, the results obtained with the use of the application mention that there is a positive effect and it contributes with learning. However, he considers the application like a tool to support the teaching process as a contribution to the playful component, which allows the learner to consolidate their knowledge in a fun way without the help of a tutor. Likewise, the results of this study show that as it is frequently practiced in the application, greater skill and knowledge are obtained, which allows increasing the level of abstraction in solving problems.

The different works that are related to the cited documents allow demonstrating the importance of incorporating technological tools to the development of logical thinking in children, even more so if these tools can be incorporated in the first stages of learning. In this way, it is possible to contribute to the development of cognitive skills through logical-mathematical reasoning, for this, the technology must adapt to the needs of children, and that it does not cause adverse effects.

3 Materials and Methods

3.1 Design

A systematic review of the documentation on the characteristics of the activities used to develop the logical reasoning to associate them with the operation of the proposed device was carried out.

3.2 Search Strategy

To define the characteristics of the activities to be carried out on the electronic device, scientific articles were searched using online databases such as ScienceDirect, Scielo, and Google Scholar.

3.3 Inclusion and Exclusion Criteria

The systematic review of all types of documents published in scientific databases had as inclusion criteria the electronic devices used in the development of logical reasoning for children between five and seven years of age, while the main exclusion criteria were the tools that do not use technology for its operation.
4 Development of the Electronic Toy as a Tool for Logical Reasoning

The developed electronic device comprises a minicomputer such as the Raspberry Pi, a graphic interface through a screen of the type Thin Film Transistor—Liquid Crystal TFTDisplay (-LCD) for the development of the exercises, as input elements are It has a color sensor, an RF-ID tag reader and several push buttons (see Fig. 1).

For the interaction with the child, there is a 3.5-inch TFT screen that is equivalent to $480 \times 320$ pixels, where the menus and the games will be shown, this will present four options to solve the proposed exercise, except for the game with numbers which requires all number symbols from 1 to 10 presenting more options to find the correct answer. The Fig. 2 shows the diagram of the math game menu, this scheme is similar to the menu for the geometric shapes, and color comparison games, this selection scheme that appears on the touch screen is associated with the buttons installed on the device, allowing the selection of options can also be made from these elements.

4.1 Logical Reasoning Games

Games that use a methodological strategy for learning produce great value due to their characteristics, one of them is being suitable for the first levels of child development, this is the reason why various mathematicians, psychologists, and educators have developed and experimented with logic games for children. These games are classified according to two criteria that are applied in the development of the proposed device.

The first criterion is related to the attributes here, there are games of differences and similarities that have been developed, of denial among others, then there is
the criterion related to the material to be used, there are games that use logical blocks, polygonal blocks, cards with objects between others, there are also games with graphic materials that use cards with drawings, sheets with diagrams and others, there are also games that use symbolic material like cards with attributes, cards with mathematical expressions, and verbal propositions that allow establishing values of true and false, finally, there are the logic and number games [21].

For the development of the proposed device, the characteristics of logical reasoning games were taken as a basis, using electronic elements such as peripherals of the Raspberry Pi which contains the program developed in Python to achieve the interaction of the device and children during the development of the different activities proposed.

4.1.1 Games for Learning Two Basic Mathematical Operations (Addition and Subtraction)

For this section called mathematics, different games related to the operation of addition and subtraction will be designed, these games use the Technology of Radio Frequency Identification (RF-ID) with cards that represent numbers. This section has two activities, the first activity called Questions require the child to perform a mental operation of addition or subtraction to answer the question raised, the second activity presents images that must be counted by the child. Showing up next shows an example of the math game that will appear on the screen of the device (see Fig. 3).

These games were developed by taking into account what was mentioned by De Ribosa and Durán [17], many studies show that math games help in cognitive learning, because they support children in the development of their guesses, without the fear of making mistakes, besides providing a basis for mathematical learning.
In this same sense, Ferrándiz et al. [8] mention that adequate stimulation at an early age will favor the development of mathematical and logical intelligence, which will allow children to introduce these skills into their daily lives, for this the stimulation must accord to the age and characteristics of the little ones, respecting their rhythm, it must be fun, meaningful, and equipped with reinforcements to make it pleasant.

4.1.2 Geometric Shapes Games

Block-based educational games as presented by Arias [3], positively influence children to recognize different characteristics of the elements such as shapes, sizes, colors, among others, allowing the construction of sets and finding different elements, these games influence mental dexterity by making children able to recognize diverse patterns.

For the design of this class of games, this device uses the recognition of geometric figures, for this, mini RF-ID tags placed on geometric figures were used, so that children must recognize when displayed on the screen (see Fig. 4).

A selection game was also implemented using colored buttons for the child to analyze and choose the correct answer asked (see Fig. 5).

4.1.3 Association Games

These games were developed by the importance that has memorization-based learning, as Caiza et al. mentioned [15], this form of learning is the simplest because it is based on the memorization of information, but, learning is representative when new information like concepts, relationships, among others, as a result of the analysis because they are assimilated and last better.

In this game, the child needs to identify objects according to color and sound, for this purpose, several objects of the same color are displayed on the screen, and
a sound corresponding to the object will be played, an example of this exercise is shown in the Fig. 6, in which it is required to identify a bird, in this way, the child must relate the color of the object and the sound to solve the exercise.

### 4.2 Electronic Toy Design

Using the Fritzing software, the diagram of the connections is made, in this is showing how the different elements used to the construction of the electronic toy are connected, as it can be seen almost all Raspberry GP-IO (general-purpose input/output) ports are busy, most of these ports connect the TFT screen with the Raspberry Pi, additional, the connections of the buttons and LED’s are directly interconnected to the controller.

The RF-ID reader module uses four connections for the GND, VCC, SCL, and SDA pins. For the operation of the color sensor, it needs five connections for the VCC, GND, Signal, S2, and S3 pins, for this element the S2 and S3 pins are configured so that the output of this sensor works in the frequency of 20 kHz (see Fig. 7).
**Fig. 6** Color matching game

**Fig. 7** Color matching game
4.2.1 PCB Design for Buttons and LED’s

The PCB board has two VCC, and GND power outputs from the Raspberry Pi, for the connection of buttons the resistors were configured in Pull Up to maintain a logical state of one always to the controller’s GP-IO input. Lastly, they are made the connections of the protection resistors of the LED’s that through terminals will be connected to the Raspberry controller. The Raspberry pi has 3.3 V and 5-volt output pins, due to precautions in the use of GP-IO ports, it was decided to use the 3.3 V outputs to supply the circuit with the buttons and the color sensor that can support between 3 and 5 V.

To the final design of the PCB board, the Proteus Ares software was used, which allows showing the final location of the resistors and the terminals that will allow the connection of the buttons and LED’s. In total, there are eight terminals, eight resistors, and four connection pins for the signal input when a button is activated (see Fig. 8).

4.2.2 Device Programming

As mentioned earlier, the programming was carried out in the Python program, for which the corresponding flow diagram (see Fig. 9), it presents the operation logic of the device, generally, when it starts automatically, it shows the game presentation screen. Then the main menu will appear, here it is possible to choose from among the three exercises created, of mathematics where the main objective is the use of numerical reasoning, that of shapes to identify different types of geometric figures and that of colors to identify an object according to certain characteristics.
To the proposed exercises, there are three forms to solve it, the first using buttons, the second with RF-ID tags, and the last using the color sensor, the figure shows the example of the math game’s operating logic (see Fig. 10), this has two kinds of exercises, the first one for questions and the second one for numbers. The first option has different problems to solve by pressing the button with the correct answer, while the exercise with numbers will use the RF-ID cards corresponding to each number, according to the problem, the card corresponding to the response to the RF-ID reader should be approached. This logic also applies to figure exercises.
4.2.3 **End Device**

For the elaboration of the structure of the prototype, MDF wood is used as a material whose shape similar to that of a video juces machine to be built in this material is presented in the see Fig. 11, the structure has the screen perpendicular to the child, It has buttons with the same color as the options that appear on the touch screen. The color sensor and the RF-ID reader will be placed under the buttons, when they are required to be used to prevent objects from approaching the screen as a precaution, they will also be placed separately to avoid interference during operation, thus facilitating the interaction between the toy and the child.
5 Performance Tests and Results Analysis

Once the assembly of all the components of the prototype was completed, including the details, so that they could capture the attention of a child before using it, the operation of each element that will allow interaction with the children was first verified, these results are shown in Table 1.

The tests carried out on each element determine the correct operation of each one according to the parameters set out in the design, with this validation, it is possible to use the prototype to assess the level of difficulty of the exercises created.

The following general test consists of the use of the device and the solution of the exercises proposed by children, given the limitation presented worldwide by the

| Table 1 Operation of device elements |
|--------------------------------------|
| Element                              | YES | NO |
| LED lighting according to the color of the menu | X   |    |
| Using the program options with the buttons | X   |    |
| Using the program options from the touch screen | X   |    |
| Detection of Tags and RF-ID cards    | X   |    |
| RF-ID sensor response with different exercises | X   |    |
| Color sensor response with different exercises | X   |    |
COVID-19, the results obtained correspond only to 10 children, so the result of its usefulness once this health crisis is overcome, these results will be presented in a future article as feedback that allows developing a general idea about the positive characteristics and possible improvements not only of the exercises proposed, but also of the operation of the device. The following Table 2 gives a summary of these results.

With the results obtained, in general, the developed prototype presents positive characteristics such as capturing children’s attention, the level of difficulty tests, their reasoning capacity, and generates an activity that involves the adults who are responsible for the child.

### 6 Conclusions

As a result of the implementation of this research project, the following conclusions are reached.

For the programming of the different games to be developed in the prototype, the Python language was developed because it is simple, flexible, has many tools that help to focus on the development of the programming and not on the details, making modifications such as increasing the games to the device without this requiring new programming.

The use of different electronic elements such as the RF-ID reader, sensors, display screen, and RF-ID cards allowed creating an easy-to-use project, that allows being a tool to help in the development of logical and mathematical thinking, this was evidenced by the children who were part of the functional tests of the device.

The elaborated device met the goal of being used as an electronic toy by being striking and fun as showed by the children who used it by showing interest in solving math problems and object recognition since the different electronic elements were used playful way for children in solving problems of mathematical, logical reasoning.

The elaborated program allows the combination of different mathematical logic exercises, such as multiple-choice questions with addition and subtraction, spatial
reasoning with the objects of geometric figures, the reasoning of fraction problems, comparison of colors that contribute to the development of the child’s logical reasoning using the prototype.

For the importance of the interaction between a child and their parents, the device was developed so that the activities are not carried out autonomously by the child, but require the participation of their parents because these types of activities contribute to the emotional development of the child.

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